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Source Category Survey: Industrial Incinerators

Acurex Corp.
Morrisville, NC

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The report contains background information which was used for determining the need for new source performance standards (NSPS) for industrial incinerators in accordance with Section 111 of the Clean Air Act. The industrial incinerator population is surveyed and categorized by process type, capacity, class of owner, and other factors. Incinerator designs, control strategies, and state and local regulations are discussed. The impact of a potential NSPS on particulate emissions is calculated.

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1. INTRODUCTION

The Clean Air Act (CAA), as amended in August 1977, requires the U.S. Environmental Protection Agency (EPA) to control the discharge of pollutants into the atmosphere. The Act contains several regulatory and enforcement options for control of emissions from stationary sources. Options include (1) National Ambient Air Quality Standards (NAAQS) implemented through State Implementation Plans (SIPs) for these standards, (2) new source performance standards (NSPS), and (3) national emission standards for hazardous air pollutants (NESHAPS).

Section 111 of the CAA, as amended August 1977, requires EPA to issue emission standards of performance for new and modified sources that may contribute significantly to air pollution whose emissions could endanger public health or welfare. The standards of performance shall reflect the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact, and energy requirements). No new plant can be built if it will result in violation of an NAAQS, even if it meets the NSPS.

Before initiating the development of NSPS, EPA generally prepares a source category survey to decide whether standards are justified. If the finding is positive, the survey also determines the availability of data required to set standards. This report presents the results of the source category survey for industrial incinerators.

For the purposes of this study, an industrial incinerator has been defined as any combustion unit used in the process of burning a nongaseous industrial waste stream which does not recover any heat for a useful purpose. There are other ongoing and proposed EPA studies that encompass liquid waste incinerators, waste-fired boilers, and commercial incinerators. Since these categories are being evaluated in other projects, they were excluded from this study.

The necessary information for the source category survey was gathered through the following activities:

1. Collection of industrial incinerator population and growth data from 22 state and 16 local air pollution control agencies; various offices of the EPA and Department of Energy (DOE); trade associations of industries that use incinerators such as Cotton Inc. and the Peanut Growers Association; and manufacturers of incinerators.
2. Collection of emissions data from literature searches, EPA research staffs, EPA regional enforcement staffs, State environmental protection agencies' records, incinerator manufacturers, control equipment manufacturers and users of incinerators.
3. Development of an understanding of incinerator operations and problems through a literature review.
4. Collection of data on applicable pollution control devices from literature, control device manufacturers and users, State air pollution control agencies and EPA offices.
5. Compilation of present State and Federal regulations on airborne emissions from industrial incinerators.

Based on the data collected during this study, it is concluded that the overall number of industrial incinerators is rapidly declining. It is expected that the combustion of industrial waste in steam generators and landfilling of some wastes will replace the need for industrial incinerators. The only exceptions to the general trend in reduced incinerator demand are two types of resource recovery units--those used to recover copper from scrap wire and those used to burn varnish from electric motor windings.

New installations of small-capacity copper wire incinerators are projected to average five units per year between 1980 and 1985. No large-capacity copper wire units are expected to be installed. New installations of the small-capacity units are expected to cease by 1985. A typical small-capacity copper wire unit has the potential to emit 45 tons of particulates per year; however, they are generally controlled through SIPs and actually emit less than 3.6 tons per year.

New installations of motor incinerators will probably average 100 units per year between 1980 and 1985. A typical motor unit has the potential to emit 3.5 tons of particulate per year; however, they are generally controlled and actually emit less than 0.25 tons per year.

The benefit from an NSPS is estimated in terms of the total weight of particulate matter prevented from entering the atmosphere annually. The maximum benefit for an industrial incinerator NSPS if promulgated in 1980 is estimated to be 250 megagrams of particulate matter per year for sources constructed between 1978 and 1985. Since the resource recovery segment of industrial incineration accounts for 173 megagrams (Mg) (70 percent) of this potential reduction, the ambient impact of typical copper wire and electric motor incinerators was considered. These are the only two types of resource recovery units for which noticeable new installation activity is expected. The maximum local ambient air impact for particulate matter, assuming pessimistic parameters for pollutant dispersion, was estimated to be a 24-hour average concentration of 26 micrograms per cubic meter.

The quantity of air pollutant emissions which each category will emit, or will be designed to emit, must be considered in determining priorities for promulgating standards for categories of major stationary sources. The prioritization process must also consider the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare, the mobility and competitive nature of each such category of sources, and the consequent need for nationally applicable new source standards of performance. These requirements for prioritizing categories of major stationary sources are mandated by Section 111 of the CAA, as amended in August 1977.

The reduction in the quantity of emissions or maximum benefit to be gained from a standard for industrial incineration is small when compared to the potential benefit from developing NSPS for other categories. The ambient impact of units for which noticeable new installation activity is expected is not anticipated to endanger the public health or welfare. In addition, the sources in the category are not very mobile, and the competitive nature of the associated industries does not currently necessitate a nationally applicable NSPS. Therefore, it is recommended that EPA not develop a new source performance standard for industrial incineration at this time.

2. INDUSTRIAL INCINERATOR SOURCE CATEGORY

In this section, the industrial incinerator source category is defined, the designs of the units are discussed, and a methodology for classifying the units by design is explained. This explanation is followed by a discussion of emerging incinerator technologies as well as other emerging technologies that will provide alternatives to incineration.

2.1 DEFINITION OF SOURCE CATEGORY

An industrial incinerator is any combustion unit used in the process of burning a nongaseous industrial waste stream which does not recover any heat for a useful purpose. An industrial waste stream is any waste stream which is, by weight, composed of more than 50 percent of waste generated at a manufacturing establishment or collected by a resource recovery establishment. Restricting the definition of industrial incinerators to furnaces which do not recover heat differentiates incinerators from waste-fired steam generators, hot water generators, and process heaters. Other parameters such as design or type of waste have not proved to be useful in defining these categories. Because municipal waste generally contains less than 50 percent industrial wastes, the industrial incinerator definition excludes units burning municipal waste from the category.[1] Included in this source category, however, are municipally owned incinerators that burn primarily industrial wastes. Commercial and institutional waste-burning units are also excluded from the source category by the industrial waste stipulation of the definition. In addition, liquid organic waste incinerators owned by the chemical industry, although included in the industrial incinerator definition, are excluded from this study because they are part of another EPA study.

Waste-fired steam generators are being studied under EPA's nonfossil-fueled boilers. The commercial and institutional incinerator source categories are also part of a separate investigation (which has currently been discontinued).

2.2 PRINCIPLES OF INCINERATOR DESIGN AND DESCRIPTION OF CONVENTIONAL DESIGNS

Incineration is a combustion process used to change the chemical or physical characteristics of waste by oxidation which, even under ideal combustion conditions, results in inorganic solid residues (ash) and the exhaust gases, carbon dioxide (CO_2) and water vapor. Further, because the waste burned in incinerators is often a heterogeneous mixture, ideal conditions are difficult to achieve, resulting in incomplete combustion. When incomplete combustion occurs, the exhaust gases also contain carbon monoxide (CO), hydrocarbons (HC), and uncombusted particles of waste. Incinerator designs, therefore, are the result of efforts to ensure complete combustion within the economic constraints imposed by the nature of incinerator fuel and the costs of incinerator manufacture.

Actual combustion occurs in the combustion chamber of the incinerator. The combustion chamber is lined with fire brick, castable refractory, or some other refractory which maintains high incinerator temperatures and safe operating conditions by preventing heat loss to the outside. The refractory material also stores the heat produced by combustion and allows self-sustaining incineration of waste with high heating values without the use of auxiliary burners. The combustion chamber should be designed with a volume large enough to retain the gas flow for a sufficient time to allow complete combustion. However, an excessively large chamber absorbs additional heat, making adequate temperatures in the combustion zone difficult to maintain.

Incinerators may also be designed with two combustion chambers. Two-chamber incinerators have a secondary chamber to combust the gases produced from incomplete combustion in the primary chamber. Secondary chambers are beneficial because they allow better mixing of the volatile combustion gases and increase the retention time of the combustibles. They also permit higher temperatures in the primary combustion chamber by delaying the introduction of excess air until uncombusted gases enter the secondary chamber.

Auxiliary burners must be provided to sustain the combustion if the heating value of the waste is insufficient to be self-sustaining. Even when the waste is capable of sustaining combustion, auxiliary burners are generally used during startup to ignite the waste and heat the combustion chamber.

The oxygen necessary for combustion, which is provided by air from outside the combustion chamber, can be supplied by either natural or mechanical draft. A mechanical system can use either forced draft or induced draft fans. In induced draft systems, the fan is usually located between the incinerator and the stack. In these cases, the hot gases must be cooled to protect the fans.

Air can be supplied to the combustion process from either above or below the incinerator grate. Underfire air is supplied to the incinerator under the grate supporting the waste; the air then passes through the waste. In this configuration, the air helps to dry moist waste, but care must be exercised not to supply too much air to avoid entrainment of particulate matter in the gas stream. Overfire air, on the other hand, is distributed over the waste charge. In addition, some air is usually provided in the secondary chamber for secondary combustion and for additional mixing of the combustion gases.

Providing the amount of oxygen required to achieve stoichiometric conditions is difficult; because it is impossible to mix the waste, oxygen, and fuel completely, air must be supplied in excess of stoichiometric requirements. The amount of excess air in the combustion chamber can be varied to control the temperature--i.e., the more excess air, the lower the temperature in the combustion zone. The excess air required may be introduced into the primary combustion chamber; however, in practice, less than the required amount of air is introduced into this chamber. This "starved air condition" in the primary chamber results in incomplete combustion. The incomplete combustion products are then combusted in the secondary chamber where additional air is supplied.

In the secondary chamber, proper mixing of the volatiles and excess air is required; otherwise, some of the volatiles may pass through the chamber without being combusted. Therefore, the incinerator is designed to create turbulence through a series of baffles or constrictions which prevent stratification of the gas mixture. The directional and velocity shifts produced by baffles cause the volatiles and oxygen to mix.[2] Turbulence can also be created by introducing the combustion air tangentially into either combustion chamber, causing a cyclonic gas stream flow.

2.2.1 Design Classification by Combustion Air Supply

Incinerators may be classified according to the method of supplying the combustion air. Combustion air can be supplied by either natural draft or mechanical draft.

Natural Draft. In natural draft units, the negative pressure in the exhaust stack draws the combustion air into the combustion chamber. Since the natural draft units depend on the rising of hot gases in the stack to draw in the combustion air, the air supply cannot be effectively controlled. Therefore, in a natural draft unit, the amount of combustion air varies considerably and ranges from excess air to starved air conditions.

During startup these units have difficulty achieving desired combustion temperatures because more air is introduced than is necessary for combustion. Since the air supply cannot be controlled, most of the air is supplied to the primary combustion chamber. Thus, not only is the combustion zone cooled, but the velocity of the gas stream in the primary chamber is also increased, causing excessive entrainment of particulate matter.

Mechanical Draft. Mechanical draft units operate with combustion air supplied by either forced draft or induced draft fans. Because the air is supplied mechanically, it can be controlled and varied as required. As noted earlier, the amount of air is varied not only to supply excess air, but also to control the temperature in the incinerator. As a result of this ability to control air flow, mechanical draft incinerators are more efficient and emit fewer air contaminants than comparable natural draft units.

Mechanical draft units can be operated as either starved air or excess air units. In a mechanical draft starved air unit, the combustion air to the primary combustion chamber is limited to a fraction, typically 25 percent, of the required air.[3] This low input of air allows the proper primary chamber temperature to be maintained, keeps the gas stream velocity low to prevent entrainment of particulate matter, and results in incomplete combustion. The products of the incomplete combustion then pass into the secondary chamber where complete combustion occurs. Nearly all the noncombustibles remain in the primary chamber. This design, as shown in Figure 2-1, precludes the use of the single-chamber physical design that is described later in this report.[4]

Alternatively, mechanical draft excess air units provide enough air or slightly more air than is required to achieve stoichiometric conditions. This method allows proper combustion with less entrainment of particulate matter than can result in natural draft units.

2.2.2 Design Classification by Physical Structure

The existing population of industrial incinerators represents several major physical design types. These designs are grouped by paths which the gases and wastes follow through the incineration system. The path of the gases is generally controlled by the number of combustion chambers. The paths of the waste both before and after combustion are controlled by movement of the hearth or kiln or by the number of hearths. These different types affect retention times, waste handling capabilities, and the interaction between the gaseous and solid or liquid phases flowing in the system. Each design category will be described separately.

Single-Chamber. The typical single-chamber incinerator consists of a furnace box containing a combustion chamber and ash pit which are divided as shown in Figure 2-2 by a grate. Waste is fed and ignited through the charging door located above the grate. A natural gas burner and ash cleanout door are located below the grate. The charging door is designed for overfire air and the cleanout door for underfire air.

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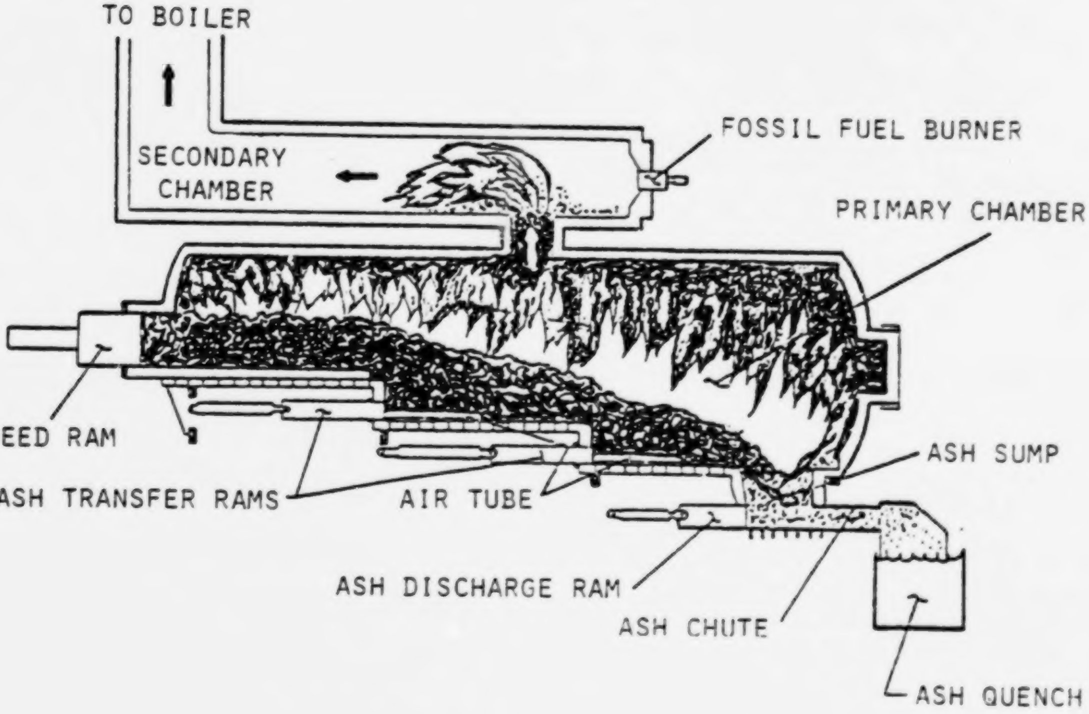
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PRIMARY CHAMBER
FEED RAM
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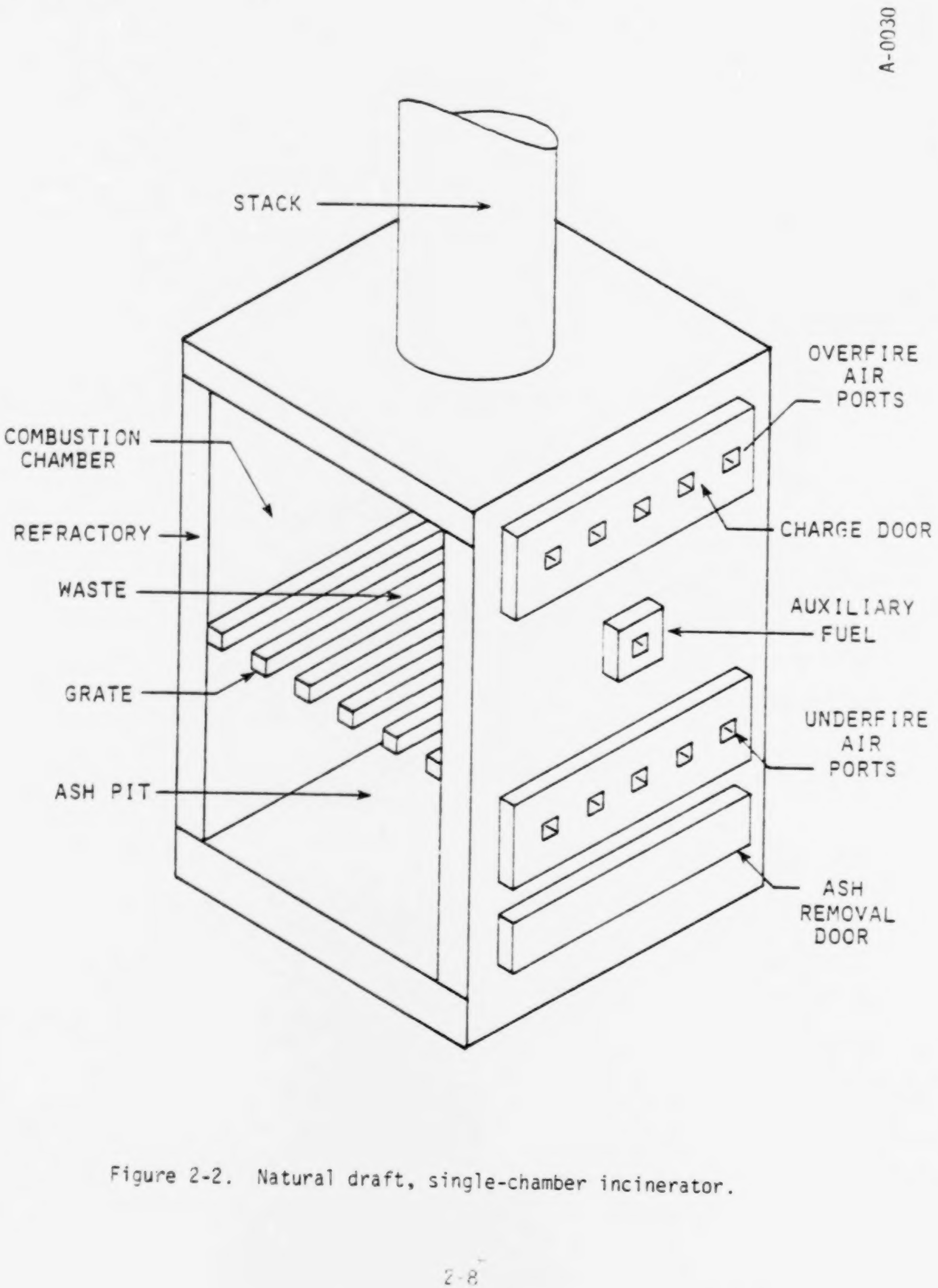
ASH SUMP
ASH DISCHARGE RAM
ASH CHUTE
ASH QUENCH

Figure 2-1. Starved air incinerator.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STACK
OVERFIRE AIR PORTS
COMBUSTION CHAMBER
CHARGE DOOR
REFRACTORY
WASTE
AUXILIARY FUEL
GRATE
UNDERFIRE AIR PORTS
ASH PIT
ASH REMOVAL DOOR

Figure 2-2. Natural draft, single-chamber incinerator.

The advantages of the single-chamber incinerator are its simplicity and low cost. However, the disadvantages are inherent in the design, including inadequate mixing of combustion gases, short retention time, extreme temperature fluctuations, and, under some conditions, entrainment of particulate matter in the flue gases. Incomplete combustion also results in excessive emissions of hydrocarbons and carbon monoxide. The incomplete combustion of hydrocarbons in single-chamber incinerators often results in characteristic dark smoke and foul odors. Because of increasingly stringent air pollutant emission standards, the market for single-chamber incinerators has been decreasing. Several State air pollution control agencies (Georgia, Texas, New Jersey, Montana, California and Mississippi) have banned single-chamber incinerators outright. Although these incinerators may be improved by adding afterburners and temperature air controls, operational and maintenance problems have negated most such attempts.

Multiple-Chamber. Multiple-chamber incinerators generally consist of two or three interconnected refractory-lined chambers designed for maximum combustion of the waste fired. The typical multiple-chamber incinerator has a primary or ignition chamber, which is divided into a combustion section and an ashpit. The ashpit is positioned by a grate on which the refuse is burned. The primary chamber is provided with both overfire and underfire air controls. The mixing or downpass chamber, which adjoins the primary chamber, is separated from the primary chamber by the bridge wall. At the top of the bridge wall is an opening called the flame port, which allows the combustion gases to travel from the primary into the mixing chamber. The mixing chamber is provided with secondary air ports to supply required secondary combustion air. The secondary combustion chamber, the last chamber, is separated from the mixing chamber by the curtain wall. The curtain wall contains a port at the bottom which allows the combustion gases to pass from the mixing chamber into the secondary combustion chamber.

The combustion process in a multiple-chamber incinerator proceeds in two stages--the primary or liquid/solid fuel combustion in the primary chamber, followed by secondary or gaseous-phase combustion in the mixing and secondary combustion chambers. Ignition and combustion of the liquid or solid refuse occur in the primary chamber. As burning proceeds, the moisture and volatile components of the fuel are vaporized and partially oxidized in passing from the ignition chamber through the flame port connecting the ignition chamber with the mixing chamber. From the flame port, the volatile components of the refuse and the products of combustion flow down through the mixing chamber into which secondary air is introduced. The combination of adequate temperature and additional air, augmented by mixing chamber or secondary burners as necessary, assists in initiating the second stage of the combustion process. Turbulent mixing, resulting from the restricted flow areas and abrupt changes in flow direction, furthers the gaseous-phase reaction. In passing through the curtain wall port from the mixing chamber to the final combustion chamber, the gases undergo additional changes in direction accompanied by expansion and final oxidation of combustible components. Fly ash and other solid particulate matter are collected in the combustion chamber by wall impingement and simple settling. The gases finally discharge through a stack or a combination of a gas cooler (for example, a water spray chamber) and induced draft system.[5]

Most multiple-chamber incinerators sold today are modular package units, generally consisting of metal shells lined with castable refractory.

A typical modular package unit is shown in Figure 2-3.[6] Thus, multiple-chamber incineration is well suited for the combustion of all solid organic wastes, including trash, x-ray film, and wire. The better mixing of combustion gases, longer retention time, and more constant temperatures allow multiple-chamber incinerators to generate fewer air pollutants than single-chamber incinerators. Particulate emissions from multiple-chamber incinerators are typically one-tenth to one-fourth those from single-chamber units burning the same type and amount of waste.[7]

Rotary Kiln. The rotary kiln is a cylindrical, horizontal, refractory-lined shell mounted at a slight incline which rotates slowly when in operation. A typical rotary kiln incinerator is shown in Figure 2-4.[8] Rotary kiln incineration is well suited for the combustion of all organic waste, including sewage sludge and hazardous wastes. Solid waste is charged at the higher end and travels the length of the kiln because of the revolving and tumbling motion of the inclined kiln. Liquid and gaseous wastes can also be added through auxiliary nozzles.[9] The waste is combusted while passing through the kiln, and the noncombustible waste drops out the lower end. The tumbling action of the rotary kiln results in continuous removal of ash and continuous exposure of new surfaces for oxidation. The discharge end of a rotary kiln is often hooded so that collected combustion gases are exhausted to a secondary combustion chamber.

The retention time of the charge can be controlled by varying the rotational speed of the kiln. Retention time of the gas stream and oxygen supply are varied as required by the air supply controls. A relatively constant temperature can be maintained by varying the feed rate of waste and by directly controlling the auxiliary burners. Mixing of the combustion

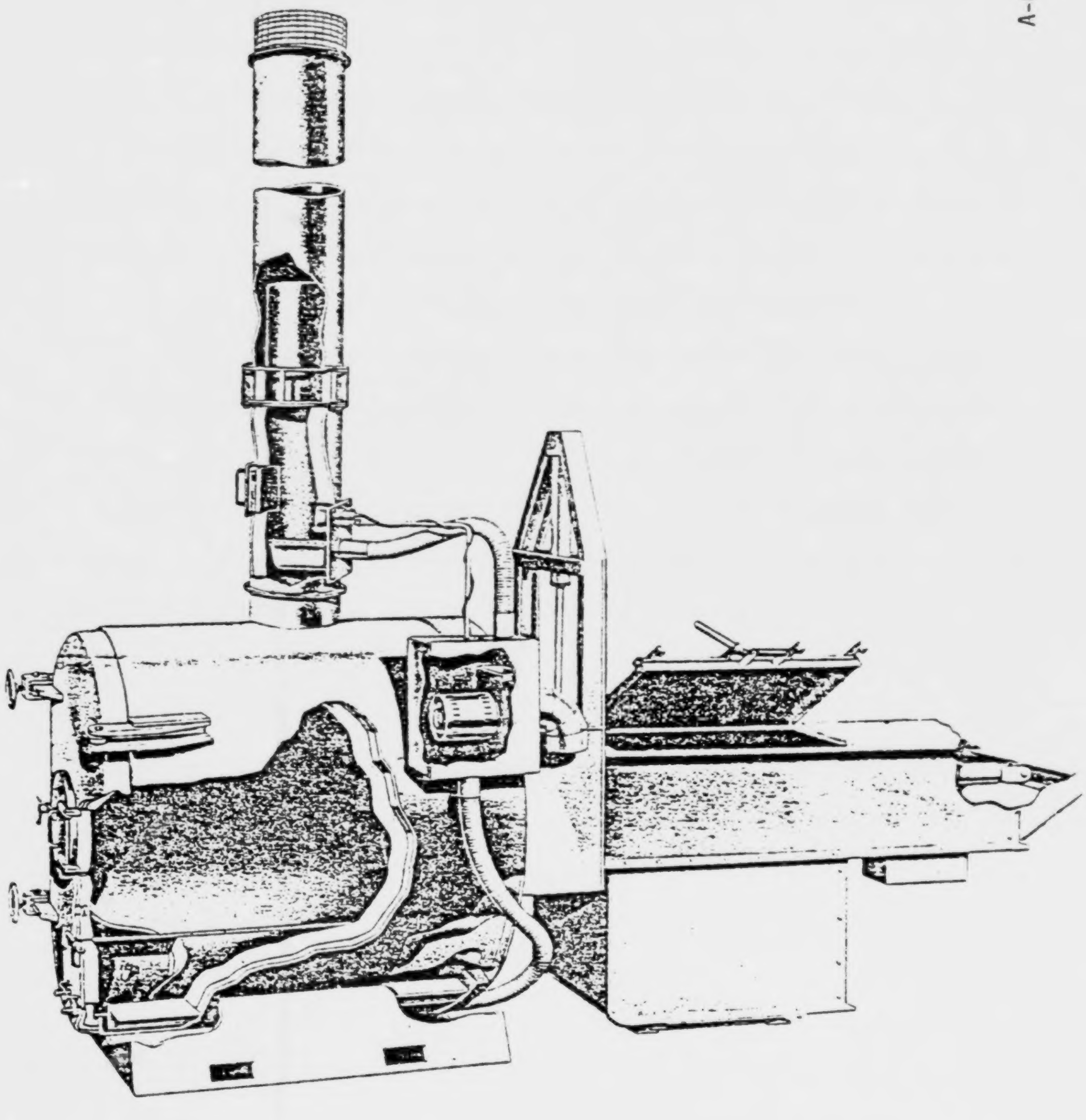

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Figure 2-3. Package incinerator.

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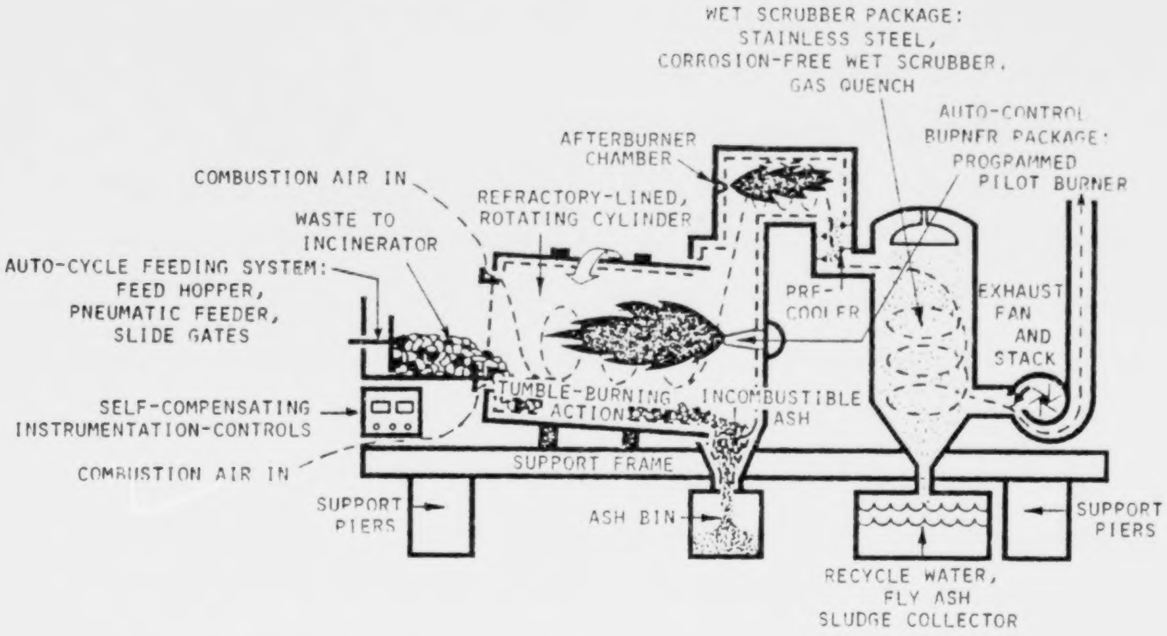
WET SCRUBBER PACKAGE:
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PILOT BURNER
AFTERBURNER
CHAMBER
COMBUSTION AIR IN
REFRACTORY-LINED,
ROTATING CYLINDER
WASTE TO
INCINERATOR
AUTO-CYCLE FEEDING SYSTEM:
FEED HOPPER,
PNEUMATIC FEEDER,
SLIDE GATES
PRE-
COOLER
EXHAUST
FAN
AND
STACK
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INSTRUMENTATION-CONTROLS
TUMBLE-BURNING
ACTION
INCOMBUSTIBLE
ASH
COMBUSTION AIR IN
SUPPORT FRAME
SUPPORT
PIERS
ASH BIN
SUPPORT
PIERS
RECYCLE WATER,
FLY ASH
SLUDGE COLLECTOR

Figure 2-4. Rotary kiln incinerator.

gases is achieved through the tumbling action of the kiln and the turbulence caused by directional changes as the gas stream travels from the kiln to the secondary combustion chamber. Since the requirements of combustion (retention time, turbulence, air supply and temperature) are all controllable, they can be manipulated as required for complete combustion.

The inner diameter of the kiln must be designed sufficiently large to keep the velocity of the gas stream traveling through it low enough to prevent entrainment of particulate matter. Most rotary kiln incinerators are sold as package equipment and are equipped with wet scrubbers for additional control of air pollutants.

An advantage of rotary kiln incineration is that the rotation of the kiln reduces the number of refractory repairs necessitated by flame impingement and slagging. Since the refractory surface is continually changing spatially, there is no prolonged flame impingement on one specific portion of refractory. Unfavorable aspects of this type of incineration include erosion and thermal spalling of the refractory. Waste material tumbling inside the kiln causes abrasion, which in turn erodes the refractory. Thermal spalling, which occurs at the discharge end of the kiln, is caused by the thermal shock created by the inrush of air at the end plate seal. This spalling requires periodic replacement of a small section of refractory. Neither erosion nor spalling results in excessive maintenance.

Rotary Hearth. The rotary hearth incinerator, shown in Figure 2-5, consists of a circular combustion chamber with a rotating hearth.[10] The waste is charged on the hearth which slowly rotates while the waste is combusted. The retention time of the waste charge can be controlled by the rotational speed of the hearth. At a point in the rotation, the uncombusted

A-0033

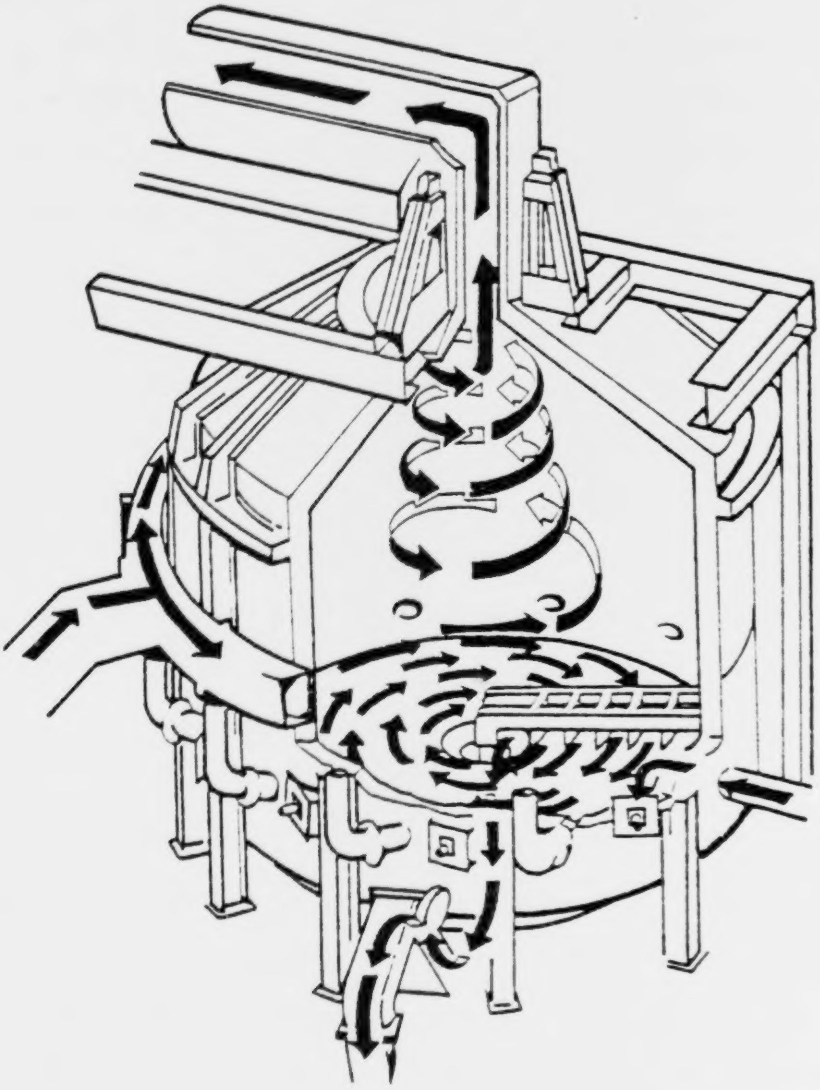

Figure 2-5. Cyclonic rotary hearth incinerator.

ash drops from the hearth into the ash discharge pit. The rotation of the hearth allows continuous feeding with a uniform bed on the hearth. The feed and rotational rates can be adjusted to maintain optimal constant temperature. The oxygen supply to the hearth is often controlled to make the rotary hearth incinerator operate as a pyrolyzing unit. The combustion chamber is equipped with auxiliary burners to supplement heating needs. Rotary hearth units are usually designed so that combustion gases follow a cyclonic path through the combustion chamber to the outlet. This cyclonic action provides the necessary turbulence to mix the combustion gases completely.

Rotary hearth units usually burn either solid or liquid waste and are well suited for burning sewage sludge. Units burning solid waste are charged on the outer perimeter of the hearth, and the waste is carried around the combustion chamber where it is combusted. When waste material is added, the partially burned waste is moved toward the center and along a spiral path toward the central ash discharge pit.[11] Typically, liquid and semiliquid wastes are uniformly sprayed by nozzles across the hearth. The unburned residue is scraped off the hearth into the ash pit by a plow mechanism.

Multiple-Hearth. The multiple-hearth incinerator consists of a refractory-lined cylindrical steel shell containing several hearths arranged in a vertical stack and a hollow central rotating shaft with rabble arms. A multiple-hearth unit is shown in Figure 2-6.[12] Operating capacity is related to total hearth area. The number of hearths varies from 4 to 13 with diameters ranging from 1.4 to 7.6 m (5.4 to 25 ft). Capacities of multiple-hearth incinerators vary from 90 to 3,600 kg/hr (200 to 8,000 lb/hr).

A-0034

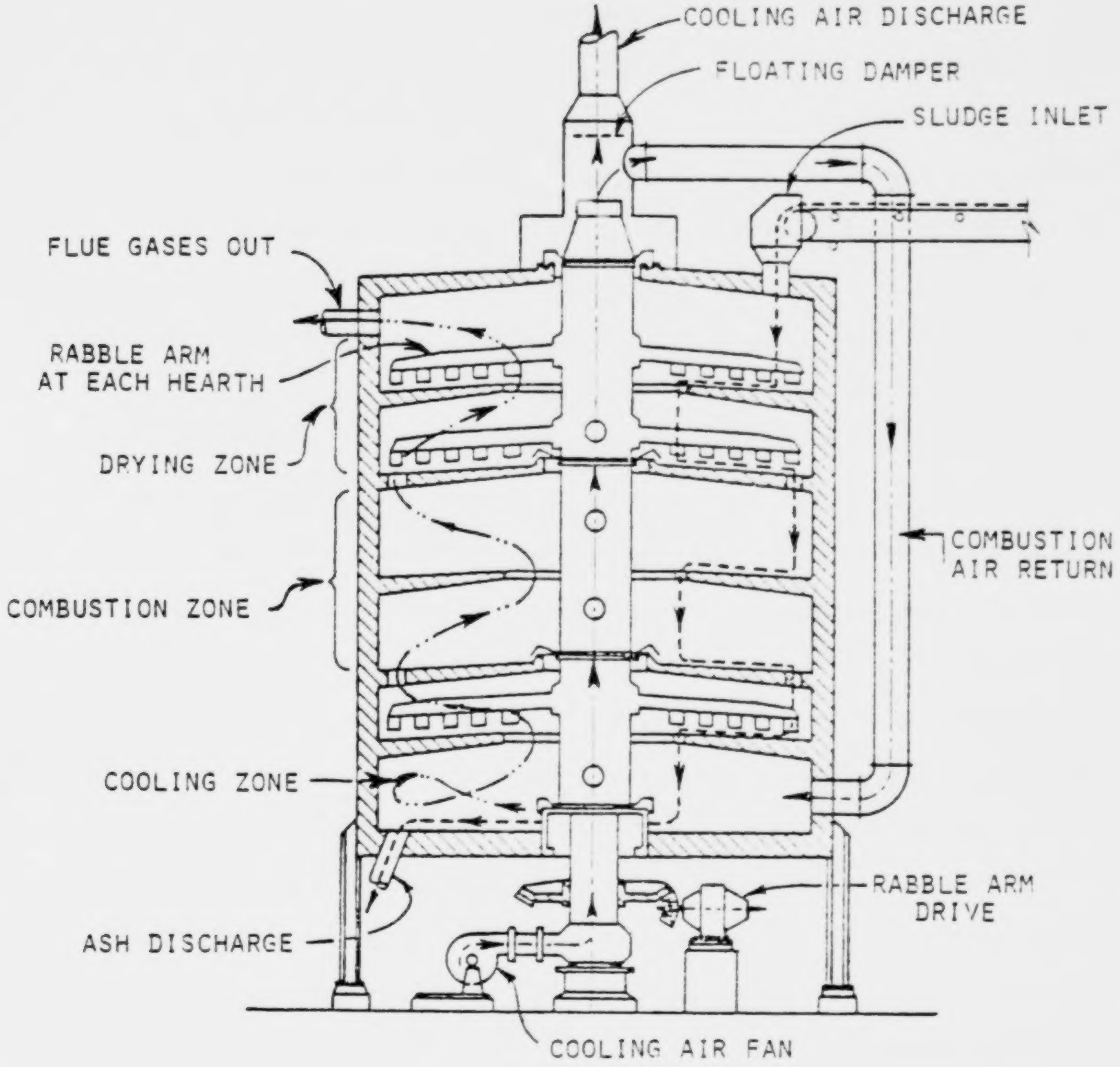
COOLING AIR DISCHARGE
FLOATING DAMPER
SLUDGE INLET
FLUE GASES OUT
RABBLE ARM AT EACH HEARTH
DRYING ZONE
COMBUSTION AIR RETURN
COMBUSTION ZONE
COOLING ZONE
RABBLE ARM DRIVE
ASH DISCHARGE
COOLING AIR FAN

Figure 2-6. Multi-hearth incinerator.

Multiple-hearth incineration is suitable for the combustion of most organic wastes. Solids are normally fed directly to the top hearth, greases and tars through side ports, and liquid and gaseous wastes through auxiliary nozzles. Incineration occurs in three phases. Waste material is first fed to the outer perimeter of the top hearth and is raked slowly by the rabble arms in a spiral path toward the center. Here it falls to the second hearth and is raked by the rabble arms to the outer perimeter. The waste then drops to the third hearth and is again raked to the center. The uncombusted ash finally falls from the bottom of the incinerator into the ash removal system. As shown in Figure 2-6 the three phases of incineration occur at different levels in the multiple-hearth unit. The upper hearths permit evaporation of moisture and oxidation of volatiles. The middle hearths burn the remaining wastes, and the bottom hearths cool the noncombusted ash prior to discharge. The rabble teeth continuously agitate the waste by turning it over to expose new surfaces for evaporation of moisture and oxidation of volatiles. Adequate mixing of combustion gases is ensured by the stirring of the rabble arms and the constant change in the direction of the gas stream as it travels around the hearths (which act as baffles for the gas stream).

The hollow central shaft is cooled by forced air vented out the top. A portion of this preheated air from the central shaft is piped to the lowest hearth and is further heated by the hot ash and combustion as it passes up through the furnace. The gases are then cooled as heat is absorbed by the incoming waste, evaporating any moisture present. The countercurrent flow pattern of air and waste causes the central shaft to operate as a heat exchanger, reducing heat losses and increasing incineration efficiency.[13]

Liquid Injection. Liquid injection incinerators consist of either a vertical or horizontal combustion chamber in which atomized liquid waste is burned. Liquid injection incineration is limited to waste composed of liquids and slurries which can be pumped. To increase the rate of vaporization and thus of combustion, the liquid wastes are atomized to present a heat transfer surface area as large as possible. The waste is usually atomized as it enters the combustor, by mechanical means, internal mixing nozzles, two-phase nozzles, or pressure nozzles. Droplet size is less than 40 microns in diameter. If viscosity precludes atomization, heating and mixing or other means may be necessary to reduce apparent viscosity. A forced draft is usually supplied to the combustion chamber to produce the necessary mixing and turbulence. Turbulence is also provided by firing the atomized waste tangentially to cause a cyclonic effect in the combustion chamber. Additional heated, pressurized air can be injected near the combustion chamber discharge to create an afterburner effect. The required oxygen is contained in the compressed air used for atomizing the waste. Auxiliary burners in the combustion chamber provide additional heat as needed.[14]

Conical. Conical incinerators, also known as teepee or wigwam burners, consist of a cone-shaped steel shell topped with a dome-shaped spark arrestor screen. A typical conical incinerator is shown in Figure 2-7.[15] Conical incinerators usually contain a raised grate on which fuel is dropped from a conveyor system. Overfire air is provided by natural draft through ports in the side of the shell and is often supplemented by underfire air blown under the grate by a forced air fan. Conical incinerators are not usually equipped with auxiliary burners.

A-0035

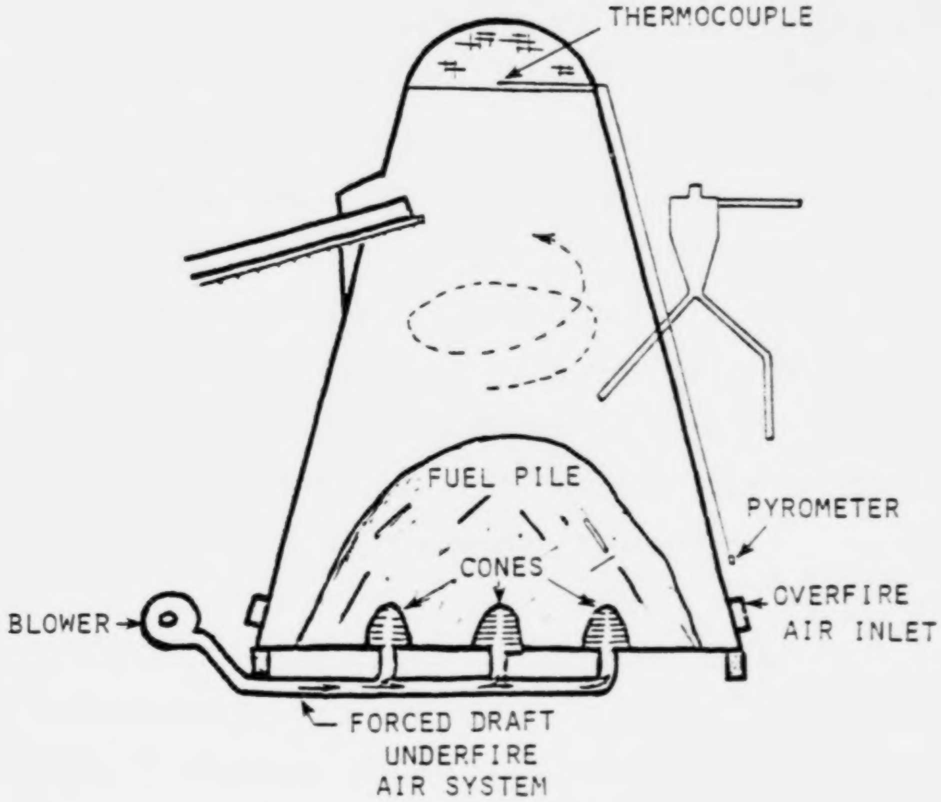
THERMOCOUPLE
FUEL PILE
PYROMETER
CONES
BLOWER
OVERFIRE AIR INLET
FORCED DRAFT UNDERFIRE AIR SYSTEM

Figure 2-7. Conical incinerator.

Conical incinerators are typically used to incinerate wood and agricultural waste. The quantities and types of pollutants emitted from conical burners vary considerably with the type of waste burned, moisture content of the waste, combustion air, and temperature. Because of poor maintenance, poor operation and low temperatures caused by too much excess air, conical incinerators are usually characterized by relatively high pollutant emissions.

Conical burners can be modified in several ways to reduce pollutant emissions caused by incomplete combustion. For example, the addition of an air supply control system will provide a means for maintaining high temperatures and supplying the correct amount of combustion air required. Providing a tangential entry for the overfire air will cause a cyclonic effect, resulting in increased turbulence and better mixing of the combustion gases. Finally, the addition of auxiliary burners will maintain adequate combustion temperatures, especially during startup.

Fluidized Bed. The fluidized bed incinerator consists of a refractory-lined cylindrical metal shell with a grid in the lower section which supports a bed of inert granular particles, such as sand. A typical fluidized bed incinerator is shown in Figure 2-8.[16] Blower-driven air enters at the bottom of the unit and travels upward through the grid and the bed. The force of the air agitates and expands or "fluidizes" the bed and causes it to act like a boiling liquid. Wastes are injected into the bed pneumatically, mechanically, or by gravity. Rapid and relatively uniform mixing of wastes and bed material occurs.

During the combustion process, combustion heat is transferred from the bed to the injected waste. Typical bed temperatures range from 760° to

A-0036

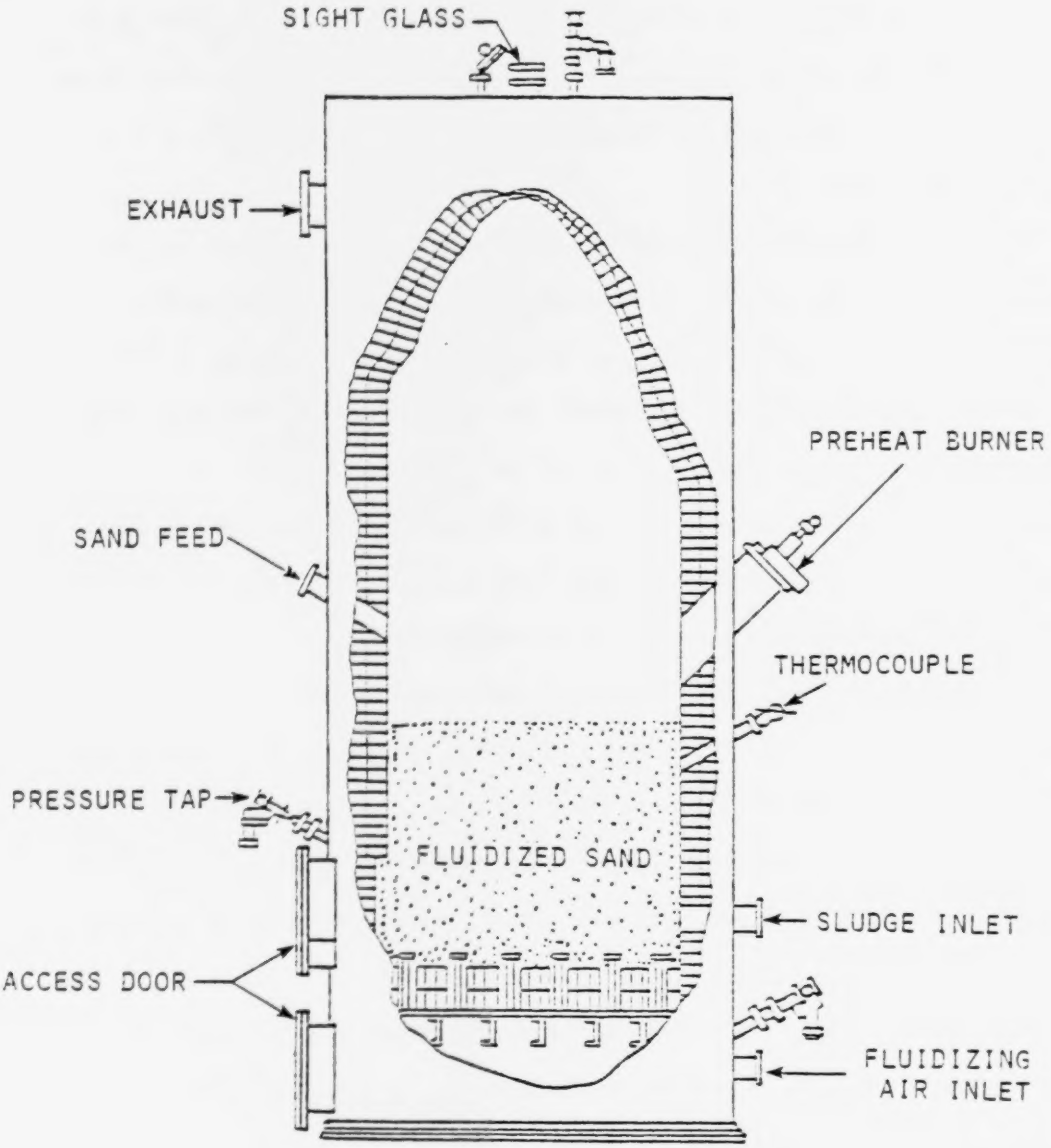
SIGHT GLASS
EXHAUST
PREHEAT BURNER
SAND FEED
THERMOCOUPLE
PRESSURE TAP
FLUIDIZED SAND
SLUDGE INLET
ACCESS DOOR
FLUIDIZING AIR INLET

Figure 2-8. Fluidized bed incinerator.

870° C (1400° to 1600° F). Because of the high heat capacity of the bed material, the heat content of the fluidized bed is approximately 142,000 kg-cal/m^3, which is about three orders of magnitude greater than the heat capacity of flue gases in typical incinerators operating in the same temperature range.[17] Because of this large heat capacity, fluidized bed incinerators are often self-sustaining and need no auxiliary fuels after startup. The heat from combustion is transferred back to the bed material. Solid materials remain in the bed until they become small and light enough to be carried off with the flue gas as particulate matter to be removed by the particulate emission control equipment. Auxiliary burners are used to heat the bed to the required combustion temperature during startup and to provide auxiliary heat when needed.

Enough fluidizing air must be supplied to fluidize the bed and provide the necessary oxygen for combustion. However, too much excess air blows bed material and products of incomplete combustion out with the flue gas and depletes stored heat energy from the bed.

The fluidized bed reactor has a minimum of mechanical components and is relatively simple to operate. The bed acts as a large heat reservoir which minimizes the amount of fuel required to reheat the system following shutdown. This feature of fluidized bed incinerators makes them very attractive for intermittent operation. Since the reactor exhaust temperatures exceed 760° C, an afterburner and supplemental fuel are not required to comply with air pollution regulations, as may be required of other incinerators in some areas. The fluidized bed incinerator will incinerate all organic waste, but it is especially suited for liquids.[18]

2.3 DESCRIPTION OF NONCONVENTIONAL INCINERATION TECHNIQUES

Stimulated by the needs for energy, the shortages of acceptable landfills, and the rapidly increasing volume of solid waste, a number of nonconventional incineration techniques are under development or have recently become commercially available. These emerging technologies are described on the following pages.

Cement Kilns. It is currently common practice to add chlorides to some cement kilns to reduce the alkali content of the cement product. By burning chlorinated hydrocarbons, both the chlorine and energy are recovered from the waste, thus reducing the cement plant's need for chlorides and fossil fuel.

In 1977, TRW conducted a study for EPA's Office of Solid Waste Management to determine the effectiveness of using cement kilns for the destruction of chemical wastes.[19] In this study, several chlorinated hydrocarbons were incinerated in a cement kiln owned by the St. Lawrence Cement Company. The kiln owned by St. Lawrence, illustrated in Figure 2-9, is 124 meters long with a diameter of 3.5 meters. Its nominal capacity is 863 megagrams (950 tons) per day.

Gases from each kiln pass through a six-section electrostatic precipitator. Gases from the precipitators are then exhausted through a common stack. Number 6 fuel oil is burned in a single burner at the center of the burner pipe. For these tests, chlorinated hydrocarbons were fed just above and to one side of the center using different sizes of nozzles for proper atomization at different flow rates. Tests were performed burning chlorinated aromatics and polychlorinated biphenyls (PCBs). In general, the TRW data indicated that no detectable levels of organic waste constituents were in either

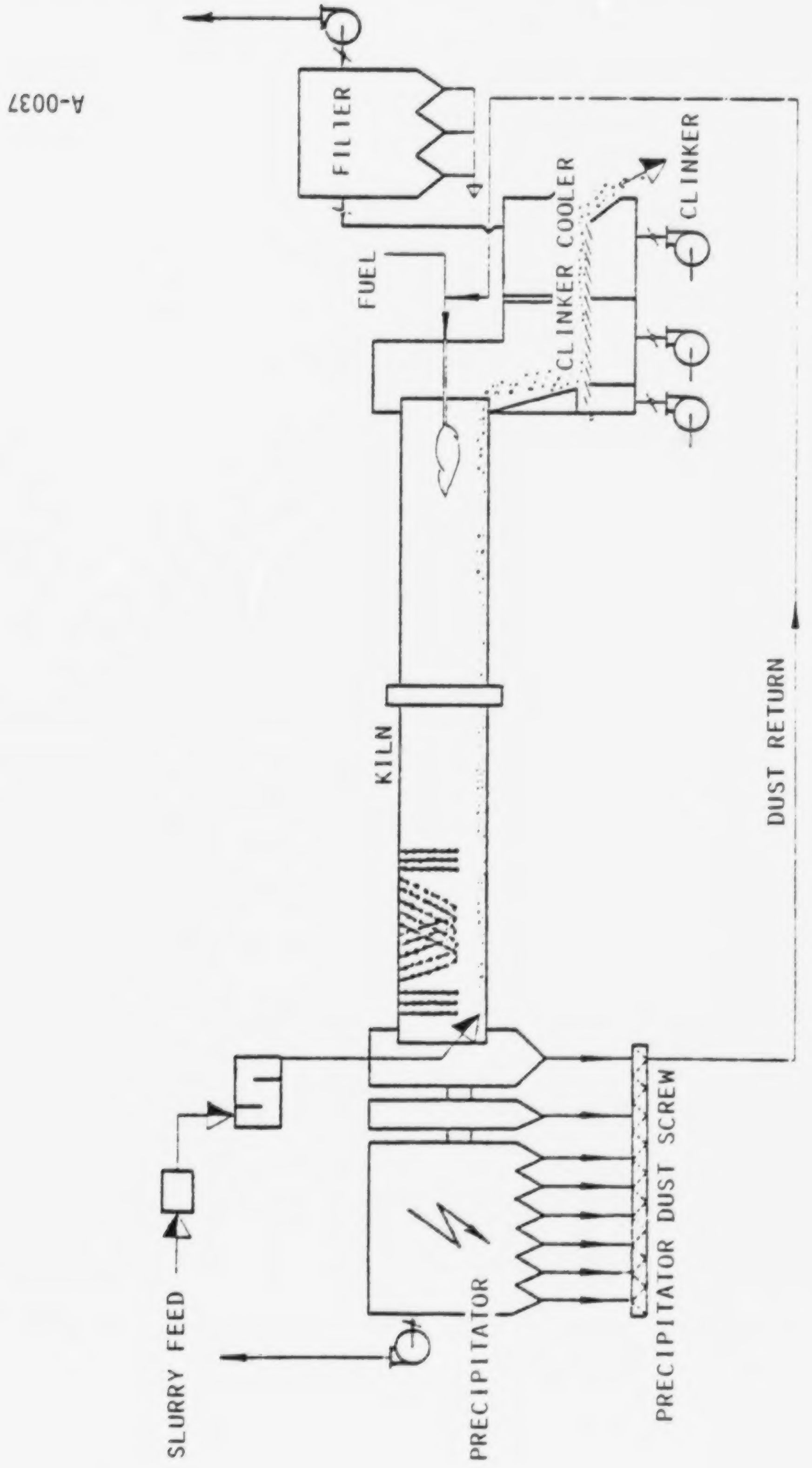
SLURRY FEED
PRECIPITATOR
PRECIPITATOR DUST SCREW
KILN
DUST RETURN
FUEL
CLINKER COOLER
CLINKER
FILTER
A-0037

Figure 2-9. Cement kiln.

effluent or solid samples, and that no significant differences between any of the samples were caused by addition of the chlorinated hydrocarbon wastes to the wet process cement kiln. Organic combustion efficiencies were reported as 99.989 percent for the chlorinated aromatic waste burns and as 99.986 percent for the waste burns containing PCBs and other chlorinated hydrocarbons. These efficiency percentages are based on total hydrocarbon content of kiln emissions.

Infrared Incineration. An infrared incinerator consists of an all-electric furnace which uses infrared lamps and an electric heat source. Recent developments in infrared lamps, coupled with the advent of silicon-controlled rectifiers, semiconductor controls, and ceramic reflector materials, have provided an economical means for applying and controlling radiant energy.

In an infrared incinerator, a high-temperature belt conveyor carries the waste through a drying zone into a combustion zone. A battery of infrared lamps initiates and maintains the combustion in the combustion zone, which is mounted just above the belt. The conveyor belt then discharges the ash into a hopper at the end of the machine. The lamps and end seals are cooled by drawing in outside air through cooling air ducts. This air, which becomes heated, is then used as combustion air. Combustion air is exhausted through a wet gas scrubber or other air pollution device. Since the infrared incinerator does not use oil or gas as an auxiliary fuel, it requires significantly lower volumes of air than other types of incinerators. The infrared unit is designed to use only the amount of air actually required for the process itself, and this amount is automatically controlled by electronic sensors. Thus, the size requirements for air handling and pollution control equipment can be drastically reduced.[20]

Molten Salt Incineration. Molten salts have long been used in the metallurgical industry to recover metals, especially aluminum. The molten salt process is now being adapted to the disposal of gaseous, liquid, and solid wastes. The molten salt combustion chamber consists of a refractory-lined chamber partially filled with a molten salt. A schematic view of a molten salt combustion process is shown in Figure 2-10.

In the basic molten salt concept for waste disposal, the waste is injected below the surface of a molten salt bath. The waste is added in such a manner that any gas formed during combustion is forced to pass through the molten salt before it is emitted into the atmosphere. Typically, salt is composed of 90 percent sodium carbonate and 10 percent sodium sulfate. In the reactor, temperatures are usually maintained at some point in the range of 810°-980°C (1500°-1800°F).[21] Lower temperatures can be achieved by using a lower melting point salt such as potassium carbonate. The heating value of most highly organic waste is sufficient to liberate enough thermal energy to heat the reactants. Pyrolysis of the feed material occurs first, and, depending on the oxygen input and the reactor temperature, the pyrolyzed gases may be combusted in the reactor or in an afterburner. In most cases, the pyrolyzed gases are combusted in the reactor.

Sodium carbonate is alkaline and reacts instantly with acidic gases such as HCl and SO_2. As a result, air pollutant emissions from molten salt processes are generally low.

Total Incineration (Slagging). Total incineration is characterized by the conversion of all waste to solidified slag and flue gases. In contrast to conventional incineration, which produces ash at temperatures around 1800°F, all or part of a total incineration system must operate at

A-0038

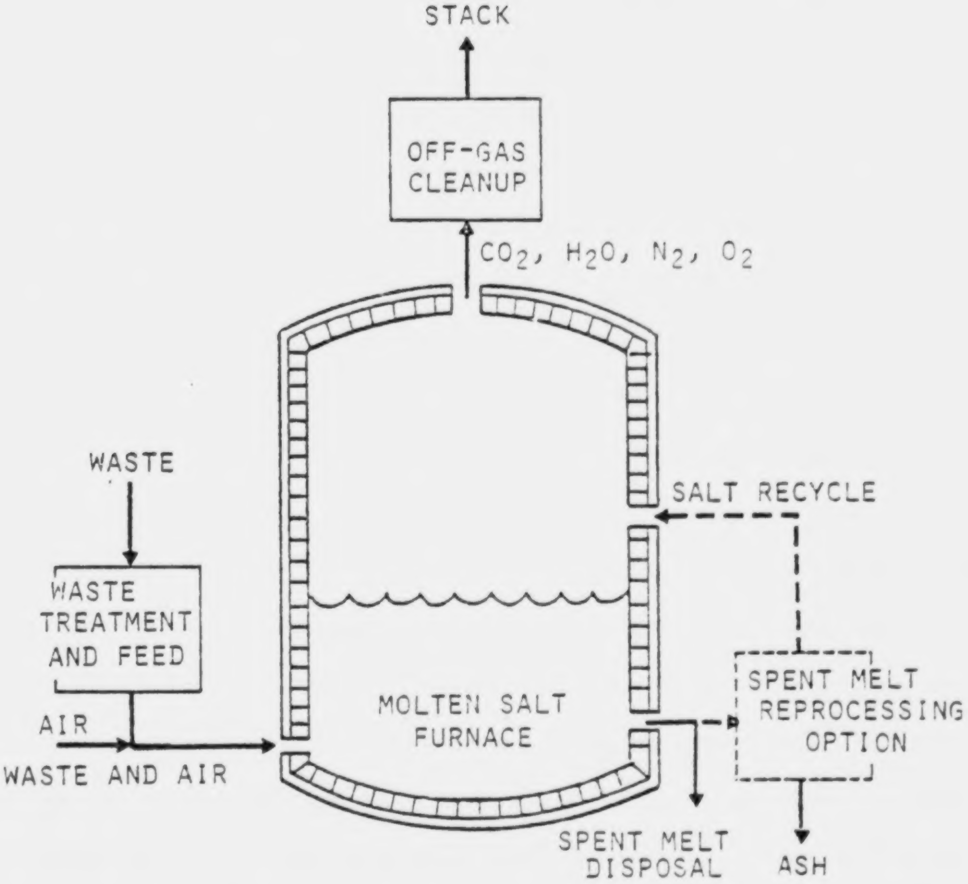
STACK
OFF-GAS CLEANUP
CO_2, H_2O, N_2, O_2
WASTE
SALT RECYCLE
WASTE TREATMENT AND FEED
SPENT MELT REPROCESSING OPTION
MOLTEN SALT FURNACE
AIR
WASTE AND AIR
SPENT MELT DISPOSAL
ASH

Figure 2-10. Molten salt incinerator.

temperatures approaching 3000°F in order to convert the ash residue to a liquid slag that can be drained from the furnace and solidified.[22] There are several different total incineration systems; however, Union Carbide's PUROX® system and the Carborundum Company's TORRAX® system represent typical total incineration processes. The PUROX® and TORRAX® systems are shown in Figures 2-11 and 2-12. The key element in the typical total incineration process is a vertical shaft furnace, which somewhat resembles a cupola. Typically, waste is charged to the top of the furnace, and oxygen is injected into the bottom hearth section. The furnace is kept full of waste which continually descends through the shaft. As the waste moves downward it is first dried and then pyrolyzed. The char which remains after pyrolysis continues downward to the hearth where it is combusted by the oxygen, providing the heat necessary to melt the noncombustible materials. The molten material flows out of the furnace where it is cooled and solidified into slag. This slag represents the smallest volume possible for the initial volume of waste. The pyrolyzed gases are drawn from the furnace and either combusted in a secondary combustion chamber or used as fuel in another process. The combustion of the pyrolyzed gas usually preheats the combustion air. The absence of excess air in the furnace, which allows for the pyrolysis of the waste into a gaseous fuel, does not cause the cooling effect as the addition of excess air would and thus does permit the high temperatures required for total incineration. The smaller volume of air used also permits a reduction in the size of required air pollution control equipment. The total incineration technique is especially interesting since it is a method for converting solid waste into gaseous or liquid fuel, and thus reduces the volume of residue to the landfill by as much as 97 percent.

A-0039

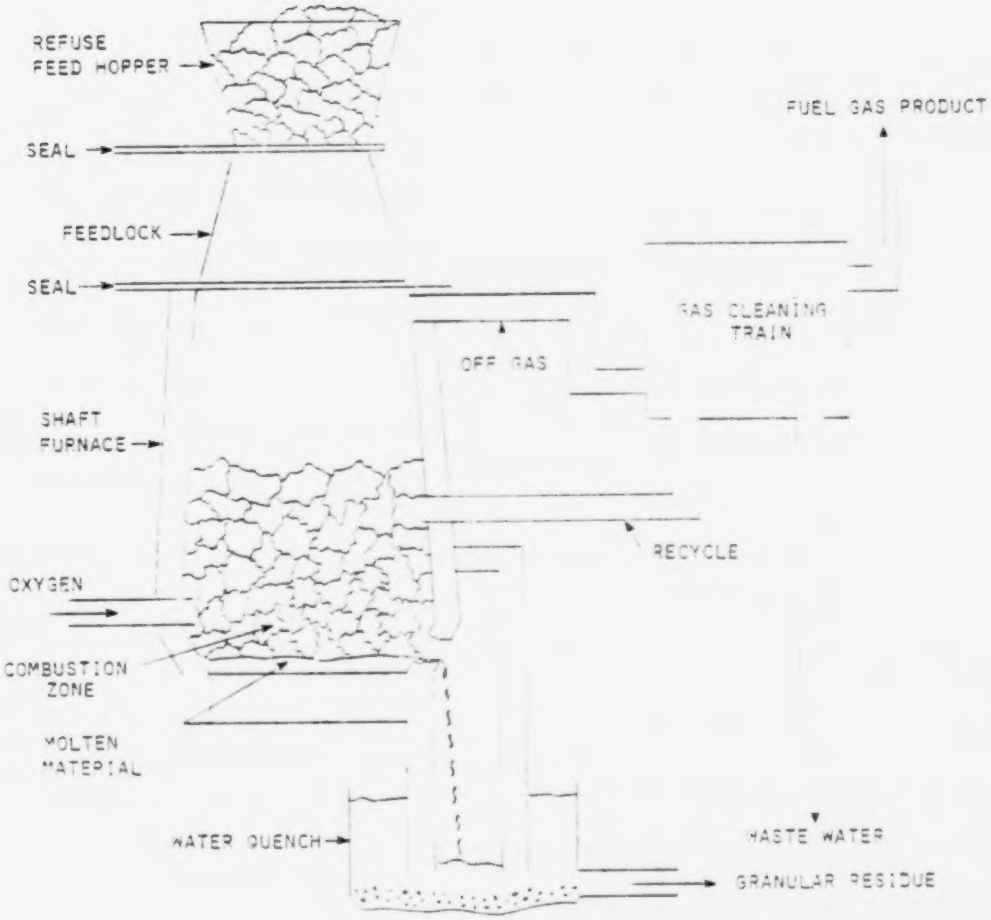
REFUSE FEED HOPPER
FUEL GAS PRODUCT
SEAL
FEEDLOCK
SEAL
GAS CLEANING TRAIN
OFF GAS
SHAFT FURNACE
RECYCLE
OXYGEN
COMBUSTION ZONE
MOLTEN MATERIAL
WATER QUENCH
WASTE WATER
GRANULAR RESIDUE

Figure 2-11. Total incineration (Purox® system).

A-0040

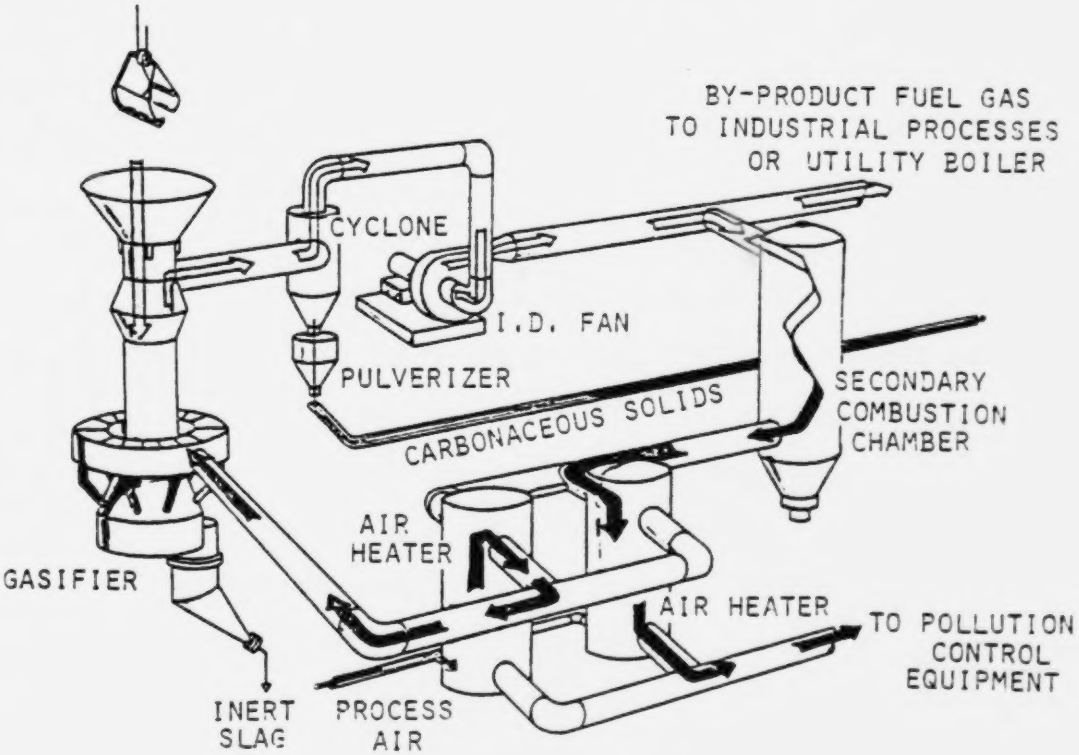
BY-PRODUCT FUEL GAS
TO INDUSTRIAL PROCESSES
OR UTILITY BOILER
CYCLONE
I.D. FAN
PULVERIZER
SECONDARY
COMBUSTION
CHAMBER
CARBONACEOUS SOLIDS
AIR
HEATER
GASIFIER
AIR HEATER
TO POLLUTION
CONTROL
EQUIPMENT
INERT
SLAG
PROCESS
AIR

Figure 2-12. Total incineration (Torrax® system).

2.4 ALTERNATIVES TO INCINERATION

This section discusses three other technologies that may prove to be alternatives to incineration that are not commonly in use today. They are briefly discussed here because of their potential future impact on the industrial incinerator population.

Wet Oxidation. Wet oxidation is a physical/chemical treatment process capable of breaking down water-soluble organics through hydrolysis and flameless oxidation. The process is carried out in an enclosed reactor at temperatures of 150°-340° C (300°-650° F) and high pressures of 3103-17,236 kilopascals gauge (450-2500 psig). Waste entering the system must be capable of being readily pumped at the temperatures and pressures used in the process. The waste is preheated to the reaction temperature via a waste heat exchanger and auxiliary heater. When injected into the aqueous solution in the reactor, complex hydrocarbons are broken down into simple hydrocarbons by hydrolytic reactions. Compressed air injected into the reactor oxidizes the simple hydrocarbon compounds to alcohols, aldehydes, acids, and ultimately to carbon dioxide and water. Once the reaction is underway, the oxidation may produce enough heat to sustain the reaction, and the auxiliary heaters may be shut down.

The exhaust gas from the unit should contain carbon dioxide, oxygen, and nitrogen. Sulfur, halogen compounds, and any remaining solids will remain in the liquid solution.[23]

Plasma Destruction. Plasma destruction is a technique which uses microwave energy to destroy waste materials. Microwave energy is applied to a carrier gas (such as helium or air) to excite its molecules and raise its electron energy levels. Essentially, very reactive free radicals are formed. The gas in this high energy condition is called plasma. The excited electrons transfer their energy to break the chemical bonds of nearby materials. Carbon-carbon bonds are among those most susceptible. Thus, theoretically, any organic waste--liquid, solid, or gas--placed into the plasma can be degraded to intermediate or ultimate products, perhaps destroying their toxic properties. Work to date has been confined to gaseous materials (though the concept is believed to be applicable to liquids and solids) and has been limited to laboratory scale units.[24]

Pyrolysis. Pyrolysis is the thermal decomposition of organic waste materials into solid, liquid, and gaseous components. Typically, organic waste is charged into a reactor and heated to 480°-810° C (900°-1500° F) in the absence of oxygen.[25] The intense heat decomposes the chemical compounds and evaporates the volatile components of the waste material. The pyrolysis of organic waste yields organic liquids, fuel gas, and char. The char contains any mineral ash or other noncombustible material present in the waste plus what is termed "fixed carbon," which represents the carbonaceous fraction of the waste that did not volatilize. The organic liquids are a complex mixture of compounds often called pyroligneous acids. The fuel gas is a mixture of combustible gases including carbon monoxide, methane, hydrogen, ethylene, and other higher hydrocarbons.[26]

Depending on the waste material, all three products can be used as fuel. The major attraction of pyrolysis is its potential for recovering useful fuels from waste materials. A pyrolysis system is shown in Figure 2-13.

2.5 DOMESTIC MANUFACTURERS OF INDUSTRIAL INCINERATORS

The number of firms in the incinerator manufacturing industry has declined over the last 10 years. This decline is due to product line

A-0041

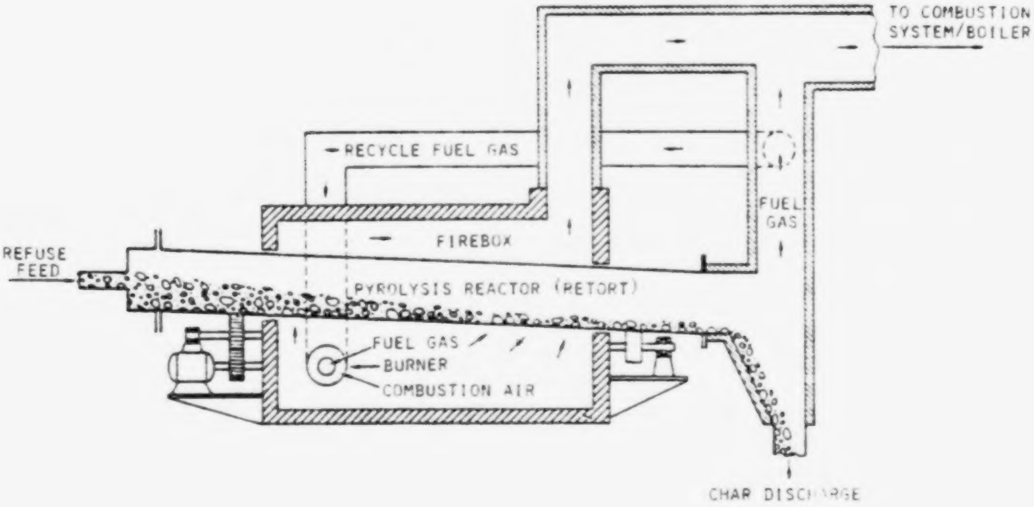
TO COMBUSTION SYSTEM/BOILER
RECYCLE FUEL GAS
FUEL GAS
FIREBOX
REFUSE FEED
PYROLYSIS REACTOR (RETORT)
FUEL GAS
BURNER
COMBUSTION AIR
CHAR DISCHARGE

Figure 2-13. Pyrolysis system (rotary kiln).

changes, business consolidations, and business failures. A listing of the manufacturers who were contacted directly or who appeared in the literature reviewed in the course of this study is presented in Table 2-1. The listing is not comprehensive, but it does include most of the manufacturers. Firms known to be out of business were not included. However, time constraints did not allow a thorough check of all the firms mentioned in the literature to ascertain whether they still exist. Table 2-1 also designates at least one source for each design discussed in this section. A source for single-chamber units is not known, as they are not believed to be available.

Table 2-1. DOMESTIC MANUFACTURERS OF INDUSTRIAL INCINERATORS

Manufacturer	Availability of designs Multiple-chamber	Rotary kiln	Multiple-hearth	Other
Consumat Systems, Inc.	X			
Econo-Therm Corp.	X			
Environmental Control Products	X			
C & H Combustion	X			
Combustion Engineering		X		Suspended cyclonic
George L. Simonds Co.	X			
Comtro, Div. of Sunbeam	X			
Lucas American Recyclers, Inc.				Rotary hearth
Rockwell International				Molten salt
Shirco, Inc.				Infrared
Dorr-Oliver, Inc.				Fluidized bed
Envirotech Corp.		X	X	
Copeland Systems, Inc.				Fluidized bed
Pickands Mather & Co.				Liquid injection
John Zink Co.				Liquid injection
Selco Products, Inc.	X			
Kelley/Hoskinson	X			
Brule, Inc.	X			

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16. Reference 10, p. IV-156.

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18. Reference 9, p. 9.

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23. Reference 9, p. 11 and 66-68.

24. Reference 9, p. 12 and 70.

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3. EXISTING REGULATIONS

In this section existing State and Federal air emission regulations that apply to industrial incinerators are compiled and summarized. A typical State regulation, which was derived from the data, was used to estimate current nationwide incinerator emissions and to project future emissions at the level allowed by State implementation plans (SIPs). Only particulate and visible emission regulations were addressed by this study, since State incinerator standards generally limit only those emissions.

3.1 STATE REGULATIONS

No single, common definition for an incinerator is used by all States. Air pollution control regulations generally define an incinerator as "any device, apparatus, equipment, or structure used for destroying, reducing, or salvaging by combusting any material or substance." The State definitions usually encompass units used for volume reduction, toxicity reduction, and resource recovery. Several States regulate conical units under a separate emission standard. Particulate and visible emission standards for incinerators do exist in all 50 States; Tables 3-1 and 3-2 list these standards. The particulate emission standards are based on either the weight of the waste charged or the flue gas volume or mass. To compare the particulate emission standards, the various units of measurement on which the standards were based were converted to a common unit. The unit used most commonly in State regulations is grains/dry standard cubic foot (gr/dscf) corrected to 12 percent carbon dioxide (CO_2). A typical industrial waste composition was not found, but for purposes of this study, to convert all the units to gr/dscf, a waste composition of 50 percent cellulose and 50 percent water and a heating value

Table 3-1. OPACITY REGULATIONS FOR NEW AND EXISTING COMMERCIAL AND INDUSTRIAL INCINERATORS

	Regulation				Equivalent
State	Value	Units	Process conditions	Validity	Common regulation (% opacity)
1 Alabama	60	% opacity	3 min discharge/60 min		60
	20	% opacity	all other times		20
2 Alaska	40	% opacity		installed before 7/1/72	40
	20	% opacity		installed after 7/1/72	20
3 Arizona	exempt		.5 min discharge/60 min		exempt
	20	% opacity	all other times		20
4 Arkansas	No. 3	Ringelmann	5 min discharge/60 min		60
	No. 1	Ringelmann	all other times	built after 7/30/73	20
	No. 2	Ringelmann		built before 7/30/73	40
5 California					
6 Colorado	20	% opacity			20
7 Connecticut	40	% opacity	5 min discharge/60 min		40
	20	% opacity	all other times		20
8 Delaware	20	% opacity	3 min discharge/60 min		20
9 District of Columbia	20	% opacity	2 min discharge/60 min	existing	20
	prohibited		all other times	existing	prohibited
10 Florida	20	% opacity	≤50 TPD, 3 min discharge/60 min		20
	prohibited		all other times		prohibited
11 Georgia	20	% opacity	all other times	installed after 1/1/72	20
	40	% opacity	6 min discharge/60 min	installed after 1/1/72	40
	40	% opacity	all other times	installed before 1/1/72	40
	60	% opacity	6 min discharge/60 min	installed before 1/1/72	60
12 Hawaii	40	% opacity			40
13 Idaho	No. 2	Ringelmann	3 min discharge/60 min	built before 4/1/72	40
	No. 1	Ringelmann	3 min discharge/60 min	built after 4/1/72	20
14 Illinois	30	% opacity	all other times		30
	30-60	% opacity	3 min discharge/60 min		30-60
15 Indiana	40	% opacity	15 min discharge/60 min		40
16 Iowa	40	% opacity			40
	60	% opacity	3 min discharge/60 min during breakdowns, etc.		60
17 Kansas	20	% opacity			20
18 Kentucky	20	% opacity			20
19 Louisiana	No. 1	Ringelmann	all other times		20
	>No. 1	Ringelmann	4 min discharge/60 min		>20
20 Maine	No. 1	Ringelmann			20
21 Maryland					
22 Massachusetts	No. 1	Ringelmann			20
23 Michigan	40	% opacity	3 min discharge/60 min		40
	20	% opacity	all other times		20
24 Minnesota	20	% opacity			20
25 Mississippi	40	% opacity			40
26 Missouri	No. 1	Ringelmann		built after 2/10/72	20
	No. 2	Ringelmann		built before 2/10/72	40
27 Montana	10	% opacity			10
28 Nebraska	20	% opacity			20
29 Nevada	20	% opacity	1 min discharge/60 min		20

(continued)

Table 3-1. (continued)

	Regulation				Equivalent
State	Value	Units	Process conditions	Validity	Common regulation (% opacity)
30 New Hampshire	No. 1	Ringelmann	3 min discharge/60 min		20
31 New Jersey	No. 2	Ringelmann	3 consecutive minutes		40
	No. 1	Ringelmann	all other times		20
32 New Mexico	No. 1	Ringelmann	2 min discharge/60 min		20
33 New York (state)	40	% opacity		built before 1/26/67	40
(state)	20	% opacity		built after 1/26/67	20
(city)	No. 1	Ringelmann	3 min discharge/60 min		20
34 North Carolina					
35 North Dakota	No. 3	Ringelmann	4 min discharge/60 min		60
	No. 1	Ringelmann	all other times		20
36 Ohio	60	% opacity	3 min discharge/60 min		60
	20	% opacity	all other times		20
37 Oklahoma	No. 1	Ringelmann	all other times		20
	No. 3	Ringelmann	5 min discharge/60 min		60
38 Oregon	40	% opacity	3 min discharge/60 min	built before 6/1/70	40
	20	% opacity	3 min discharge/60 min	built after 6/1/70	20
39 Pennsylvania	20	% opacity	3 min discharge/60 min		20
40 Puerto Rico	20	% opacity	all other times		20
	60	% opacity	6 min discharge/60 min		60
41 Rhode Island	20	% opacity	3 min discharge/60 min		20
42 South Carolina	No. 1	Ringelmann	3 min discharge/60 min		20
43 South Dakota	20	% opacity	all other times		20
	60	% opacity	3 min discharge/60 min		60
44 Tennessee	20	% opacity	5 min discharge/60 min		20
45 Texas	30	% opacity	5 min average	built before 1/31/72	30
	20	% opacity	5 min average	built after 1/31/72	20
46 Utah	No.1	Ringelmann			20
47 Vermont	40	% opacity	6 min discharge/60 min	built before 4/30/70	40
	20	% opacity	6 min discharge/60 min	built after 4/30/70	20
48 Virginia	20	% opacity			20
49 Washington	20	% opacity	3 min discharge/60 min		20
	>20	% opacity	15 min/8 hr		>20
50 West Virginia	No. 1	Ringelmann			20
51 Wisconsin	20	% opacity		built after 4/1/72	20
52 Wyoming	20	% opacity			20

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Table 3-2. PARTICULATE EMISSION LIMITATIONS FOR NEW AND EXISTING INCINERATORS

	Regulation					Equivalent
State	Value	Units	Corrected to	Process conditions	Validity	Common regulation (gr/dscf @ 12% CO_2)
1 Alabama	0.1	lbs/100 lbs charged		>50 TPD		0.12
	0.2	lbs/100 lbs charged		≤50 TPD		0.24
2 Alaska	0.3	gr/dscf	12% CO_2	≤200 lbs/hr		0.3
	0.2	gr/dscf	12% CO_2	200-1000 lbs/hr		0.2
	0.1	gr/dscf	12% CO_2	>1000 lbs/hr		0.1
3 Arizona	0.1	gr/dscf	12% CO_2			0.1
4 Arkansas	0.2	gr/dscf	12% CO_2	≥200 lbs/hr		0.2
	0.3	gr/dscf	12% CO_2	<200 lbs/hr		0.3
5 California	0.3	gr/dscf	12% CO_2	typical of the 43 APCD's		0.3
6 Colorado	0.1	gr/dscf	12% CO_2		designated control areas	0.1
	0.15	gr/dscf	12% CO_2		other areas	0.15
7 Connecticut	0.08	gr/dscf	12% CO_2		built after 6/1/72	0.08
	0.4	lbs/1000 lbs	50% excess air		built before 6/1/72	0.26
8 Delaware	0.2	lbs/hr		100 lbs/hr		0.24
	1.0	lbs/hr		500 lbs/hr		0.24
	2.0	lbs/hr		1000 lbs/hr		0.24
	5.0	lbs/hr		3000 lbs/hr		0.2
9 Florida	0.08	gr/dscf	50% excess air	≥50 TPD	built after 2/11/72	0.1
	0.1	gr/dscf	50% excess air	≥50 TPD	built before 2/11/72	0.12
10 Georgia	0.1	gr/dscf	12% CO_2	≤50 TPD - type 0,1,2 waste	new (built after 1/1/72)	0.1
	0.2	gr/dscf	12% CO_2	≤50 TPD - type 3,4,5,6 waste	new (built after 1/1/72)	0.2
	0.2	gr/dscf	12% CO_2	type 0,1,2 waste	existing before 1/1/72	0.2
	0.3	gr/dscf	12% CO_2	type 3,4,5,6 waste	existing before 1/1/72	0.3
	0.08	gr/dscf	12% CO_2	≥50 TPD	new (built after 1/1/72)	0.08
11 Hawaii	0.2	lbs/100 lbs charged				0.24
12 Idaho	0.2	lbs/100 lbs charged				0.24

(continued)

Table 3-2. (continued)

State	Regulation					Equivalent
	Value	Units	Corrected to	Process conditions	Validity	Common regulation (gr/dscf @ 12% CO_2)
13 Illinois	0.08	gr/dscf	12% CO_2	2000-60,000 lbs/hr		0.08
	0.2	gr/dscf	12% CO_2	$\leq$2000 lbs/hr	built before 4/15/72	0.2
	0.1	gr/dscf	12% CO_2	$\leq$2000 lbs/hr	built after 4/15/72	0.1
14 Indiana	0.3	lbs/1000 lbs gas	50% excess air	$\geq$200 lbs/hr		0.19
	0.5	lbs/1000 lbs gas	50% excess air	<200 lbs/hr		0.32
15 Iowa	0.2	gr/dscf	12% CO_2	$\geq$1000 lbs/hr		0.2
	0.35	gr/dscf	12% CO_2	<1000 lbs/hr		0.35
16 Kansas	0.3	gr/dscf	12% CO_2	<200 lbs/hr		0.3
	0.2	gr/dscf	12% CO_2	200-20,000 lbs/hr		0.2
	0.1	gr/dscf	12% CO_2	>20,000 lbs/hr		0.1
17 Kentucky	0.2	gr/dscf	12% CO_2	$\leq$50 TPD		0.2
	0.08	gr/dscf	12% CO_2	>50 TPD		0.08
18 Louisiana	0.2	gr/dscf	12% CO_2			0.2
19 Maine	0.2	gr/dscf	12% CO_2			0.2
20 Maryland	0.1	gr/dscf	12% CO_2	<2000 lbs/hr	built after 1/17/72	0.1
	0.03	gr/dscf	12% CO_2	>2000 lbs/hr	built after 1/17/72	0.03
	0.3	gr/dscf	12% CO_2	<200 lbs/hr	built before 1/17/72	0.3
	0.2	gr/dscf	12% CO_2	>200 lbs/hr	built before 1/17/72	0.2
21 Massachusetts	0.1	gr/dscf	12% CO_2		existing	0.1
	0.05	gr/dscf	12% CO_2		new	0.05
22 Michigan	0.65	lbs/1000 lbs gas	50% excess air	0-100 lbs/hr		0.42
	0.3	lbs/100 lbs gas	50% excess air	>100 lbs/hr		0.19
23 Minnesota	0.3	gr/dscf	12% CO_2	<200 lbs/hr	existing before 8/17/71	0.3
	0.2	gr/dscf	12% CO_2	200-2000 lbs/hr	existing before 8/17/71	0.2
	0.1	gr/dscf	12% CO_2	>2000 lbs/hr	existing before 8/17/71	0.1
	0.2	gr/dscf	12% CO_2	<200 lbs/hr	new (built after 8/17/71)	0.2
	0.15	gr/dscf	12% CO_2	200-2000 lbs/hr	new (built after 8/17/71)	0.15
	0.1	gr/dscf	12% CO_2	>2000 lbs/hr	new (built after 8/17/71)	0.1

(continued)

Table 3-2. (continued)

	Regulation					Equivalent
State	Value	Units	Corrected to	Process conditions	Validity	Common regulation (gr/dscf @ 12% CO_2)
24 Mississippi	0.2	gr/dscf	12% CO_2	Design Capacity		0.2
	0.1	gr/dscf	12% CO_2	New Sources Near Residential Areas		0.1
25 Missouri	0.2	gr/dscf	12% CO_2	≥200 lbs/hr		0.2
	0.3	gr/dscf	12% CO_2	<200 lbs/hr		0.3
26 Montana	0.2	gr/dscf	12% CO_2	>200 lbs/hr	existing before 9/5/75	0.2
	0.3	gr/dscf	12% CO_2	≤200 lbs/hr	existing before 9/5/75	0.3
	0.1	gr/dscf	12% CO_2		all others	0.1
27 Nebraska	0.2	gr/dscf	12% CO_2	<2000 lbs/hr		0.2
	0.1	gr/dscf	12% CO_2	≥2000 lbs/hr		0.1
28 Nevada	3.0	lbs/ton charged		<2000 lbs/hr		0.18
	variable	$E = 40.7 \times 10^{-5} C$	C,E = lbs/hr	>2000 lbs/hr		0.05
29 New Hampshire	0.3	gr/dscf	12% CO_2	≤200 lbs/hr		0.3
	0.2	gr/dscf	12% CO_2	>200 lbs/hr		0.2
	0.08	gr/dscf	12% CO_2	>50 TPD	built after 4/20/74	0.08
30 New Jersey	0.2	gr/dscf	12% CO_2	<2000 lbs/hr	type 0,1,2,3 waste only	0.2
	0.2	gr/dscf	12% CO_2	all others		0.1
31 New Mexico	only opacity regulations			≤50 TPD		-
	0.08	gr/dscf	12% CO_2	>50 TPD	new (built after 8/17/71)	0.08
32 New York	0.5	lbs/100 lbs charged		>2000 lbs/hr	built between 4/1/62 and 1/1/70	0.6
	0.5	lbs/100 lbs charged		≤2000 lbs/hr	built between 4/1/62 and 1/1/68	0.6
	variable (e.g., 0.3)	lbs/hr		≤100 lbs/hr	built after 1/1/68	0.36
	variable (e.g., 3.0)	lbs/hr		@1000 lbs/hr	built after 1/1/68	0.36
	variable (e.g., 7.5)	lbs/hr		@3000 lbs/hr	built after 1/1/70	0.3
33 North Carolina	0.2	lbs/hr		0-100 lbs/hr		0.24
	0.4	lbs/hr		@200 lbs/hr		0.24
	1.0	lbs/hr		@500 lbs/hr		0.24
	2.0	lbs/hr		@1000 lbs/hr		0.24
	4.0	lbs/hr		≥2000 lbs/hr		0.24

(continued)

Table 3-2. (continued)

State	Regulation					Equivalent
	Value	Units	Corrected to	Process conditions	Validity	Common regulation (gr/dscf @ 12% CO_2)
34 North Dakota	variable	lbs/hr		@100 lbs/hr		0.4
				@1000 lbs/hr		0.31
				@3000 lbs/hr		0.24
35 Ohio	0.1	lbs/100 lbs charged		≥100 lbs/hr		0.12
	0.2	lbs/100 lbs charged		<100 lbs/hr		0.24
36 Oklahoma	variable	lbs/hr		@100 lbs/hr		0.48
				@1000 lbs/hr		0.31
				@3000 lbs/hr		0.21
37 Oregon	0.3	gr/dscf		≥100 lbs/hr		0.3
	0.2	gr/dscf		>200 lbs/hr	built before 6/1/70	0.2
	0.1	gr/dscf		>200 lbs/hr	built after 6/1/70	0.1
38 Pennsylvania	0.1	gr/dscf	12% CO_2			0.1
39 Rhode Island	0.16	gr/dscf	12% CO_2	<2000 lbs/hr		0.16
	0.08	gr/dscf	12% CO_3	≥2000 lbs/hr		0.08
40 South Carolina	0.5	lbs/10^6 Btu		@10 mm Btu/hr		0.27
41 South Dakota	0.2	lbs/100 lbs charged				0.24
42 Tennessee	0.2	% of charge		≤2000 lbs/hr		0.24
	0.1	% of charge		>2000 lbs/hr		0.12
43 Texas	variable	lbs/hr		@1000 lbs/hr		0.41
				@3000 lbs/hr		0.27
44 Utah	0.08	gr/dscf	12% CO_2	>50 TPD		0.08
45 Vermont	0.1	lbs/100 lbs charged				0.12
46 Virginia	0.14	gr/dscf	12% CO_2			0.14
47 Washington	0.1	gr/dscf	7% O_2			0.11
48 West Virginia	8.25	lbs/ton		≤200 lbs/hr		0.5
	5.43	lbs/ton		>200 lbs/hr		0.33
49 Wisconsin	0.2	lbs/1000 lbs exhaust gas	12% CO_2	500-4000 lbs/hr	built after 4/1/72	0.11
	0.3	lbs/1000 lbs exhaust gas	12% CO_2	≤500 lbs/hr	built after 4/1/72	0.17
	0.5	lbs/1000 lbs exhaust gas	12% CO_2	>500 lbs/hr	built before 4/1/72	0.28

(continued)

Table 3-2. (continued)

State	Regulation					Equivalent
	Value	Units	Corrected to	Process conditions	Validity	Common regulation (gr/dscf @ 12% CO_2)
	0.6	lbs/1000 lbs exhaust gas	12% CO_2	$\leq$500 lbs/hr	built before 4/1/72	0.34
	0.15	lbs/1000 lbs exhaust gas	12% CO_2	$\geq$4000 lbs/hr	built after 4/1/72	0.08
50 Wyoming	0.2	lbs/100 lbs charged				0.24

of 10.37×10^6 J/kg (4462 Btu/lb) were assumed. The conversion factors based on these assumptions are presented in Table 3-3.

Some States have particulate emission standards that prescribe a fixed emission limit for all incinerator classifications. Other States have variable limits such as one based on capacity for some or all incinerator classifications. Forty-five States have only fixed emission limits, and they range, as adjusted, from 0.1 gr/dscf @ 12 percent CO_2 to 0.27 gr/dscf @ 12 percent CO_2. A typical emission limit value would be 0.2 gr/dscf.

Several States have different limits for new incinerators than for existing incinerators. The limit is typically 0.1 gr/dscf @ 12 percent CO_2 for new units and 0.17 gr/scf @ 12 percent CO_2 for existing units. The differentiation of emission limit requirements between existing and new sources and the occurrence of a stricter standard for new units is not commonplace enough nationwide to justify basing a typical SIP emission limitation on existing standards in States with special emission limitations for new units.

Thirty-one of the 50 States have fixed emission limits for incinerators but different ones for different classifications depending on the capacity or charge weight of the unit. The individual State standards vary not only in emission limits for a definite capacity size but also in the capacity size ranges for the limits. The most typical standard is:

- 0.3 gr/dscf @ 12 percent CO_2 for units firing less than 200 lbs per hour,
- 0.2 gr/dscf @ CO_2 for units between 200 and 2000 lbs per hour,
- 0.1 gr/dscf @ 12 percent CO_2 for units firing more than 2000 lbs per hour but less than 50 tons per day, and
- 0.08 gr/dscf @ 12 percent CO_2 for units firing more than 50 tons per day.

Table 3-3. CONVERSION FACTORS[a]

	gr/dscf @ 12% CO_2	gr/dscf @ 50% EA[b]	lb/1000 lb of flue gas @ 50% EA	lb/1000 lb of flue gas @ 12% CO_2	lb/100 lb of charge
gr/dscf @ 12% CO_2	1	0.8795	1.563	1.789	0.833
gr/dscf @ 50% EA	1.137	1	1.777	2.034	0.9471
lb/1000 lb of flue gas @ 50% EA	0.640	0.5629	1	1.145	0.533
lb/1000 lb of flue gas @ 12% CO_2	0.559	0.4916	0.873	1	0.465
lb/100 lb of charge	1.20	1.055	1.876	2.147	1

[a] English to SI unit conversions were not made because in an effort to minimize the number of conversions and the impact of assumptions, all values were converted to the most commonly used units (gr/dscf @ 12% CO_2).

[b] EA = Excess air.

Several States have specific particulate emission limits for emissions from conical burners. These standards range from 0.1 gr/dscf @ 12 percent CO_2 to 0.48 gr/dscf @ 12 percent CO_2 with an average of 0.25 gr/dscf @ 12 percent CO_2.

Visible emissions from incinerators are limited to 20 percent opacity in two States and to 40 percent opacity in five States. Eight States allow 40 percent opacity from existing sources and 20 percent opacity from new sources. The limits for the remaining States range from 10 percent to 30 percent opacity.

3.2 TYPICAL SIP STANDARD

In some States, the SIP level of particulate emissions from an industrial incinerator is dependent upon the capacity of the unit, the type of waste, and the age of the incinerator. Therefore, a typical incinerator must be defined before a typical standard can be determined. For this study, it was assumed that the typical incinerator is subject to regulations covering new sources. New sources are generally defined for SIP purposes as units installed after 1972. Based on data presented in Section 4, the typical waste is industrial waste (types 5 and 6). The capacity of the typical incinerator is 277 kg/hr (610 lb/hr). Standards applicable to this incinerator are presented in Figure 3-1. The most common emission level is 0.20 gr/dscf. Most SIP levels are nearer 0.20 gr/dscf (at the higher end of the scale) than 0.1 gr/dscf (or the lower end); therefore, 0.20 gr/dscf is selected as the typical SIP level.

3.3 FEDERAL REGULATIONS

The two new source performance standards which limit emissions from incinerators are contained in Title 40, Part 60, Subparts E and O. Subpart E

A-0190

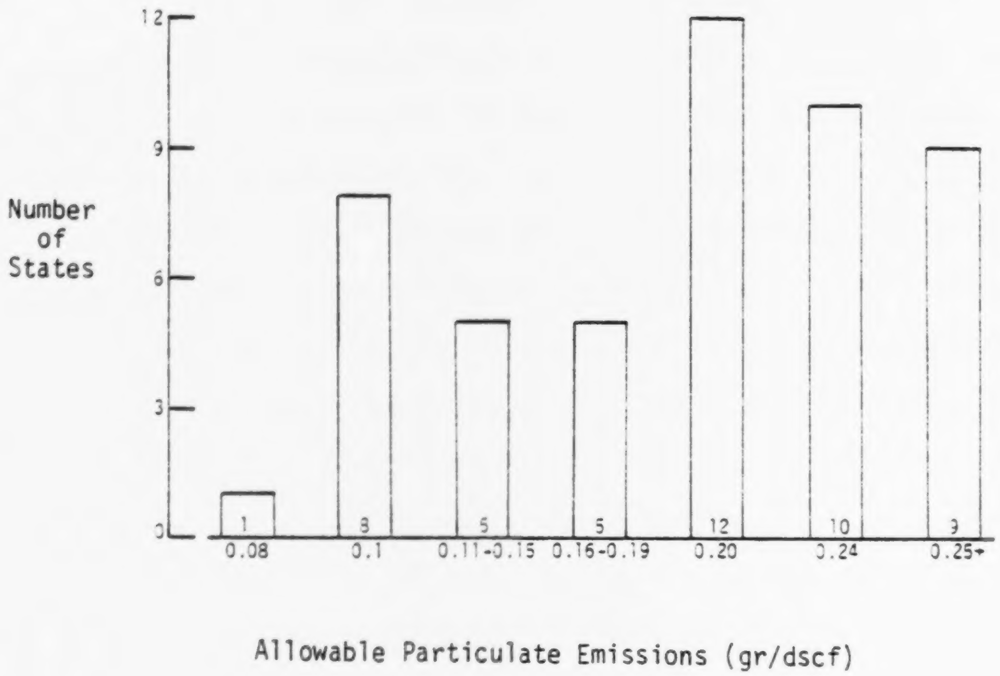


Figure 3-1. SIP emission levels for particulates.

applies to incinerators burning more than 50 tons per day of solid waste that were constructed after August 17, 1971. Solid waste is defined as refuse, more than 50 percent of which is municipal type waste consisting of a mixture of paper, wood, yard wastes, food wastes, plastics, leather, rubber, and other combustibles, and noncombustible materials such as glass and rock. This standard specifies a particulate emission limitation of 0.08 gr/dscf corrected to 12 percent CO_2. Subpart O contains Standards of Performance for Sewage Treatment Plants, which apply to sewage sludge incinerators constructed after June 11, 1973, and which burn sludge produced by municipal sewage treatment facilities. The emission standard limits particulate emissions to 1.3 lbs per ton of dry sludge input and visible emissions to 20 percent opacity. Neither standard discussed above applies to the industrial incinerator source category.

4. POPULATION AND GROWTH TRENDS

In this section the existing industrial incinerator population is described in terms of its size, ownership, capacity, use, and age. Factors that affect growth of this population are then summarized and used to project the population characteristics in 1983. The section also discusses industrial incinerators that have been classified as major sources. Some special incinerator populations outside the industrial segment are briefly discussed.

4.1 PRESENT POPULATION

To simplify the analysis in this section, the industrial incinerator population is divided into two major categories: incinerators that are physically associated with a manufacturing facility and those that are not. For purposes of this chapter, a manufacturing facility is either an establishment that generates waste as a byproduct or one that uses waste as a raw material. In the first case the incinerator is used for waste reduction and/or detoxification; in the latter case the unit is used for resource recovery. Generally, incinerators in these groups handle waste streams generated on site; however, there are exceptions such as wire incinerators and incinerators burning film and photographic materials for silver recovery. These units, if used by metal scrap yards, generally recover waste streams generated off site. Wire incinerators used by a wire company recover waste streams generated on site.

Incinerators not physically associated with a manufacturing facility consist of those owned by companies in the business of industrial waste disposal. These units are used almost exclusively for waste detoxification.

They are always located off site where they can handle the wastes of many establishments at one centralized location. In the remainder of the report these units are referred to as off-site incinerators.

4.1.1 Available Data

Minimal data are readily available on the characteristics of the present population of industrial incinerators. One reason for this is that the owners of these units are reluctant to report waste stream quantities and compositions for fear that these parameters will reveal marketing strategies or proprietary process information. Even when the information is requested on State permit applications, it is usually left blank or answered incompletely because failure to supply the data usually does not preclude approval of the application.

Most incinerator research studies have concentrated on the greater than 1890 kg/hr (50 ton/day) municipal scale units, but the majority of the industrial incinerators are in the intermediate size category of 45-1,890 kg/hr (1 to 50 ton/day). A few studies have dealt with intermediate size units or specifically addressed industrial type wastes. These studies include the Quad-City Solid Waste Project (1968); Brinkerhoff (1973); Battelle-Columbus Laboratories (1974); and Hofmann (1976).[1-4] Even these studies do not give a comprehensive picture of the industrial incinerator population. They generally deal with an entire population that includes institutional, commercial, and residential incinerators, or they concentrate on specific types of industrial incineration.

The National Emissions Data System (NEDS) operated by the National Air Data Branch (NADB) of EPA was considered as a source of population data. This system summarizes State data bases and describes incinerators by owner, design, and, in some cases, by type of waste. However, the State agencies that provide the inputs to the NEDS system are not required to report sources that have uncontrolled emissions of less than 90.9 Mg (100 tons) a year.[5] Most industrial incinerators fall below this breakpoint and may not be included in the system. The NEDS should include all large incinerators and the small units that happened to be located at a facility with another reportable source. The information in the NEDS was considered to be biased toward large units and therefore inappropriate for characterizing the national industrial incinerator population.

The Office of Solid Waste Management (OSWM) of the Environmental Protection Agency (EPA) in Washington, D.C. was also contacted for population data. Persons contacted in the land disposal division and the resource recovery division acknowledged that no comprehensive study characterizing waste streams by industrial classification and handling has been done.[6,7]

Since national population data were not available for the source category, it was necessary to compile the basic information. The industrial incinerator population is large and widely dispersed, so an actual count of the number of units in the population was not possible within the time frame and economic constraints of this phase of the project. Therefore, at the onset of this project, it was decided to use a sampling procedure to characterize the national population. After the sample was collected and analyzed, however, it was decided that sufficient data had not been compiled to conclusively characterize the segment of the industrial incinerator population used for resource recovery. To correct this deficiency, supplemental data on resource recovery units were collected from incinerator owners, incinerator manufacturers, resource recovery and related trade associations, and air pollution control agencies. Also, visits were made to five operators and one manufacturer of these units.

4.1.2 Data and Data Sources for the Sample

Selection of Sample. Although most industrial incinerators are not classified as reportable sources for the NEDS system, most State regulations require that operating permits for them be obtained from the State agency. These requirements have resulted in State records that contain a comprehensive listing of incinerators within their jurisdictions. These listings were judged to constitute the most readily available information to be used in constructing a sample.

Listings of incinerators, containing varying amounts of data, were obtained from North Carolina, Georgia, Illinois and Ohio.[8-11] Listings were also obtained from Texas and New York.[12,13] The Texas Air Control Board, however, does not require permits for sources existing prior to September 29, 1971.[14] Therefore, Texas was not included in the sample that was used to determine the size and ownership of the source category. The Texas listing did contain the most comprehensive information on incinerator use; therefore, although they were slightly biased toward new installations, these data were employed to characterize the population in terms of use. The listings from New York and New York City did not contain comprehensive data and were considered to be significantly out of date. In addition, New York was divided into smaller Air Quality Regions and all incinerators were not accounted for at the State level. Therefore, the New York data were not used to project the size of the national population but were used to determine other population characteristics.

Several criteria were applied in selecting the States to include in the sample. Recommendations were solicited from the EPA regional offices and the NADB on which States kept the most current and accessible records.[15] In addition, a State's records had to be computer retrievable and to include records from the entire State, especially from areas where local agencies had jurisdiction. Finally, the State's incinerator regulations had to be intermediate, i.e., neither excessively stringent nor lenient when compared to the regulations of other States. Based on the summary of State incineration regulations in Chapter 3, "intermediate" was judged to be 0.1 to 0.2 grains per dry standard cubic foot.

Data Availability. Available data varied from State to State. The most commonly available information was the ownership, design, capacity, use, and permit date. Information on two parameters of special interest, auxiliary fuel and control equipment, was not readily available. The type of data obtained from the listings, directly or indirectly, is shown in Table 4-1. Because the data base was a function of the particular datum of interest, the sample varied with the specific population characteristic being observed. Therefore, in each graphic or tabular representation of the data, the sample upon which the information was based is noted.

Problems with Data. A number of problems encountered when using State data should be noted. These problems involve the timeliness of the data, misuse of the codes, and lack of a consistent incinerator definition. While some areas, such as Chicago, require that an operating permit be renewed annually, in Ohio and North Carolina the renewal period is three years, and in Illinois excluding Chicago it is five. In most cases a permit is valid indefinitely. Thus, many States have no means of knowing

Table 4-1. DATA AVAILABILITY MATRIX

State	SIC code	Design	Capacity	Use	Permit date	
					Applied	Issued
North Carolina	A[a]	A[c]	A			
Georgia	A	A[b]	A[b]	A		A
Illinois	A	A[c]	A	B	A	
Ohio	A	A[b]	B			
New York	A	A[b]	A			
Texas	A	A[c]		A		A

NOTE: A = Data available for over 50% of the incinerators.
B = Data available for 15-49% of the incinerators.

[a] Derived from State manufacturing directories.

[b] Derived from incinerator manufacturer's name and model number.

[c] Derived from SCC codes.

when an incinerator ceases to operate. When the timeliness of the data was suspect, it was verified. In one State 25 percent of the reportedly existing incinerators were found to have been removed from the site, or the establishment was no longer in business.

A very common error found in all State data was misuse of the Standard Industrial Classification (SIC) Code and Source Classification Code (SCC). The SIC is a four-digit number used in the classification of establishments by type of activity in which they are engaged. The code provided the only means of describing the ownership of the population. The level of errors found in applying the codes ranged from 10 to 90 percent. In some States telephone contacts and State manufacturing directories were used to verify SICs when a high level of errors was suspected. The SCC, an eight-digit number, identifies the type of emission source. In the absence of design data or manufacturer's information, the SCC which is used by some States could provide appropriate data. It usually takes more than one SCC to describe an incinerator. One is needed to describe the design, another for the auxiliary fuel, and sometimes one for the waste. In approximately 90 percent of the cases when SCCs were used, only one was given. In addition, Catalytic and Direct Flame Afterburners were frequently misclassified as an incinerator SCC. The level of SCC errors was reduced by subjectively comparing the name of the owner or process with the codes that were given.

A significant number of incinerators as defined in this report are difficult to retrieve from the State data systems because there is not a generally accepted definition that clearly differentiates them from process equipment and waste-fired boilers. To improve the comprehensiveness of the data obtained from the States, several different computer retrievals were done for each State's data base. For example, in Georgia codes are not used to describe the type of emission point; each type is given a name instead. The computer was capable of doing alphanumeric sorts, so retrievals were done on the words "incinerator," "refuse," "waste," "furnace," and "trash." This way a "refuse disposal system" that was also an incinerator would not be overlooked. The extensive effort to cross-reference and verify the data obtained from the States should result in a sample that is timely, comprehensive and representative.

Limitations of Sampling Methodology. In order to use a sampling procedure it must be assumed that industrial incinerators are randomly distributed in the population of each industrial category. This is a reasonable assumption for the manufacturing segment of the population but not for the off-site segment. Off-site incineration is conducted by waste disposal firms. These firms have a number of alternatives from which to choose when selecting a waste disposal method. Incineration is an economically viable option only in sections of the country that have excessively high volumes of toxic waste streams. Therefore, nationally the number of waste disposal firms that select the incineration option is small. These firms are generally located in New Jersey, Louisiana, and Texas. Because they are not randomly distributed throughout the population, the sampling methodology would not be appropriate and was not used. Instead, information on the off-site segment of the population was obtained from available literature and from owners of off-site units.

The Sample. The number of establishments in the sample and the fraction of the national population represented are shown in Table 4-2. An establishment is an economic unit, generally at a single physical location where

Table 4-2. THE MANUFACTURING SAMPLE[a]

SIC code	Number of establishments in nation (1978)[b]	Number of establishments in sample (1978)[b]	Percentage included in sample
20 Food	18,195	3,367	19
21 Tobacco	167	40	24
22 Textile	5,990	2,650	44
23 Apparel	20,016	2,176	11
24 Lumber	28,881	4,904	17
25 Furniture	7,639	1,584	21
26 Paper	4,259	1,199	28
27 Printing	45,528	7,097	16
28 Chemical	8,407	2,150	26
29 Petroleum	1,494	355	24
30 Rubber, plastic	12,450	2,830	23
31 Leather	2,428	240	10
32 Stone, glass, and clay	13,385	2,784	21
33 Primary metal	5,477	1,353	25
34 Fabricated metal	27,453	7,005	26
35 Machinery	42,139	8,565	20
36 Electric machinery	13,144	2,065	16
37 Transportation equipment	9,078	1,179	13
38 Instruments	6,308	1,132	18
39 Miscellaneous manufacturing	16,052	1,974	12
TOTAL	288,490	55,649	19

[a] Sample consists of all manufacturing establishments in North Carolina, Georgia, Illinois, and Ohio.

[b] Projected from 1967 and 1972 census of manufacturers.

industrial operations are performed. The U. S. Department of Commerce, Bureau of the Census, conducts a Census of Manufacturers every five years for the years ending in "7" and "2." Data are compiled for all manufacturing establishments with one or more paid employees. The latest available census figures at the time of this study were for the years 1967 and 1972. The number of establishments in 1978 was estimated from those two years. At the time this report was done, the 1977 census was not available. As a result of having selected some very heavily industrialized States, 19 percent of the industrial establishments in the nation were represented in the sample which consisted of only four States. The sample was limited to establishments with SIC codes 20 (food manufacturing) through 39 (miscellaneous manufacturing) which includes all establishments classified by the Department of Commerce as manufacturing firms. Conical incinerators that burn wood waste were not included in this sample because it is generally agreed that they are a decreasing population because of State regulations and alternative uses for the wood.[16,17] Conical incinerators that burn something other than wood were included, as were nonconical designs that burn wood. Data on wood-burning conicals were collected from other sources and are included later in this report.

The incinerator population size was extrapolated from the sample based upon the number of establishments in the sample and in the nation. The extrapolation was corrected for under- or over-representation of a particular industry in the sample. Any incinerator owned by an establishment that could not be classified by a single two-digit SIC code was counted as a half or a third of an incinerator in each of the ownership categories. This was only necessary for 6 of the 633 incinerators found in the sample. A detailed explanation of the procedure used to calculate the size of the population is presented in Appendix C.

4.1.3 Characteristics of the Manufacturing Population

Most industrial incinerators are owned by manufacturing firms. This section describes these units in terms of ownership capacity, design, use, and age. The total number of industrial incinerators owned by manufacturing firms nationally is estimated. Except for the units that are used for resource recovery, all the population statistics presented in this section were estimated from the sample. For resource recovery units, statistical data were available from both the sample and the supplemental data collected. Whenever data on a particular characteristic of the resource recovery population were available from both data sources, the supplemental data were used. This approach was used because the supplemental data were more comprehensive and believed to be more accurate than the data collected by sampling.

Incinerator Ownership. A preliminary projection of the size of the manufacturing segment of the national industrial incinerator population is 3,043 units. The distribution of these units by ownership is shown in Table 4-3. This projection of the national population is based upon the permitting records of four State agencies. It is expected that some smaller incinerator units are not included in the State records because of either oversight or exclusion from the permitting requirements, so a national population of 3,043 units is probably conservative. Incinerators which are used for removing varnish from electric motor windings and debonding the asbestos linings from drum automobile brakes are typically smaller units and are not adequately represented in the sample. The predominant owners

Table 4-3. MANUFACTURING SEGMENT OF THE NATIONAL INDUSTRIAL INCINERATOR POPULATION

SIC code	Number of incinerators in sample[a]	Preliminary projection of incinerators in nation
35 Machinery	94	475
34 Fabricated metal	93	366
20 Food	64	338
36 Electric machinery	66	313
39 Miscellaneous manufacturing	32	255
27 Printing	29	194
28 Chemical	53	190
33 Primary metal	57	180
37 Transportation equipment	26	167
24 Lumber	19	113
23 Apparel	11	88
25 Furniture	15	78
30 Rubber, plastic	20	77
32 Stone, glass, and clay	13	58
26 Paper	14	54
38 Instruments	11	46
22 Textile	11	30
29 Petroleum	4	16
21 Tobacco	1	5
31 Leather	0	0
TOTAL	633	3043[b]

[a] Sample consists of all manufacturing establishments in North Carolina, Georgia, Illinois, and Ohio.

[b] This is not an estimate of national population because it does not adequately represent smaller units. A national population estimate is given in Table 4-10.

of these units are the electric machinery and transportation equipment manufacturing groups, SIC Codes 36 and 37, respectively. Therefore, the ranking of these two groups is probably underestimated in Table 4-3. A more comprehensive population estimate which was derived from both the sample and additional data collected is presented later in Table 4-10.

The leading owners of incinerators, based on the sample, are the machinery, fabricated metal, food, and electric machinery industries. A broad breakdown of how each of the industries uses its incinerators is shown in Table 4-4. The volume reduction category consists of any wastes that are not "toxic" or not being combusted to recover a product. It includes paper, trash, wood, and cloth. The toxicity reduction category includes anything "toxic" that was not being combusted to recover a product. No attempt was made to rigorously categorize substances as "toxic" or "hazardous" based upon any available definitions. The small amount of data and the poor descriptions of the waste given did not justify such a detailed approach. Any substance that consisted of a combustible liquid, a solvent, or explosive, or which contained a hydrocarbon such as paint was placed in the toxicity reduction category. The resource recovery category includes anything combusted to recover a product. It includes copper wire, catalysts, steel drums, brake shoes, x-ray film, and electric motors. In most of the industrial classifications, volume reduction was the predominant use. Notable exceptions to this were the chemical and petroleum industries, where toxicity reduction predominated, and the primary metal, electric machinery, transportation equipment, and instrument industries, where resource recovery predominated.

Table 4-4. USE DISTRIBUTION BY OWNERSHIP FOR SAMPLE[a]

SIC code	Incinerators in sample	Use (percent)		
		Volume reduction	Toxicity reduction	Resource recovery
35 Machinery	4	75	25	0
34 Fabricated metal	9	78	0	22
20 Food	7	100	0	0
36 Electric machinery	16	25	6	69
39 Miscellaneous manufacturing	1	100	0	0
27 Printing	2	100	0	0
28 Chemical	35	43	54	3
33 Primary metal	13	23	0	77
37 Transportation equipment	5	20	0	80
24 Lumber	3	100	0	0
23 Apparel	1	100	0	0
25 Furniture	0	N/A	N/A	N/A
30 Rubber, plastic	5	100	0	0
32 Stone, glass, and clay	4	75	0	25
26 Paper	1	100	0	0
38 Instruments	1	0	0	100
22 Textile	5	80	20	0
29 Petroleum	1	0	100	0
21 Tobacco	0	0	0	0
31 Leather	0	N/A	N/A	N/A
TOTAL	116			
		52	20	28

[a] Sample consists of incinerators in Georgia, Illinois, and Texas with use data available.

The capacity is broken down by ownership in Table 4-5. If the tobacco industry unit is deleted, because the sample is too small to provide any significant data, the table is more informative. The modified table shows that the largest mean capacity, 708 kg/hr (1,560 lb/hr), was found in the lumber industry, where the units are used for the reduction of wood waste. The transportation industry had the second largest mean, 411 kg/hr (904 lb/hr). These units are primarily used to recover the metal brake shoes from discarded bonded brakes by debonding the used asbestos pad. Smaller mean capacities of 74 and 110 kg/hr (163 and 242 lb/hr) were found for the primary metal industries. In the primary metal group the predominant use is the recovery of silver halide salts from exposed x-ray films. In the printing group the predominant use is for volume reduction of paper and trash.

Design. Information from the State data on the design of incinerators was very limited, and available information was not very accurate. States that used words as descriptors usually went only so far as "incinerator." Those that used codes merely broke the design types into single, multi-, and other. Discussions with State agency officials have established that the definition of a controlled air incinerator varies. Because of these problems, the accuracy of the design information was considered to be questionable. Whenever possible, manufacturer's name and model numbers were used to find missing design data or to corroborate information that was given. Given design data were categorized in the following manner. Anything designated "starved air" was classified as a mechanical draft, starved air unit. Units referred to as "controlled air," with no additional descriptors, were classified as mechanical draft, excess air units. Units

Table 4-5. CAPACITY DISTRIBUTION BY OWNERSHIP IN SAMPLE[a]

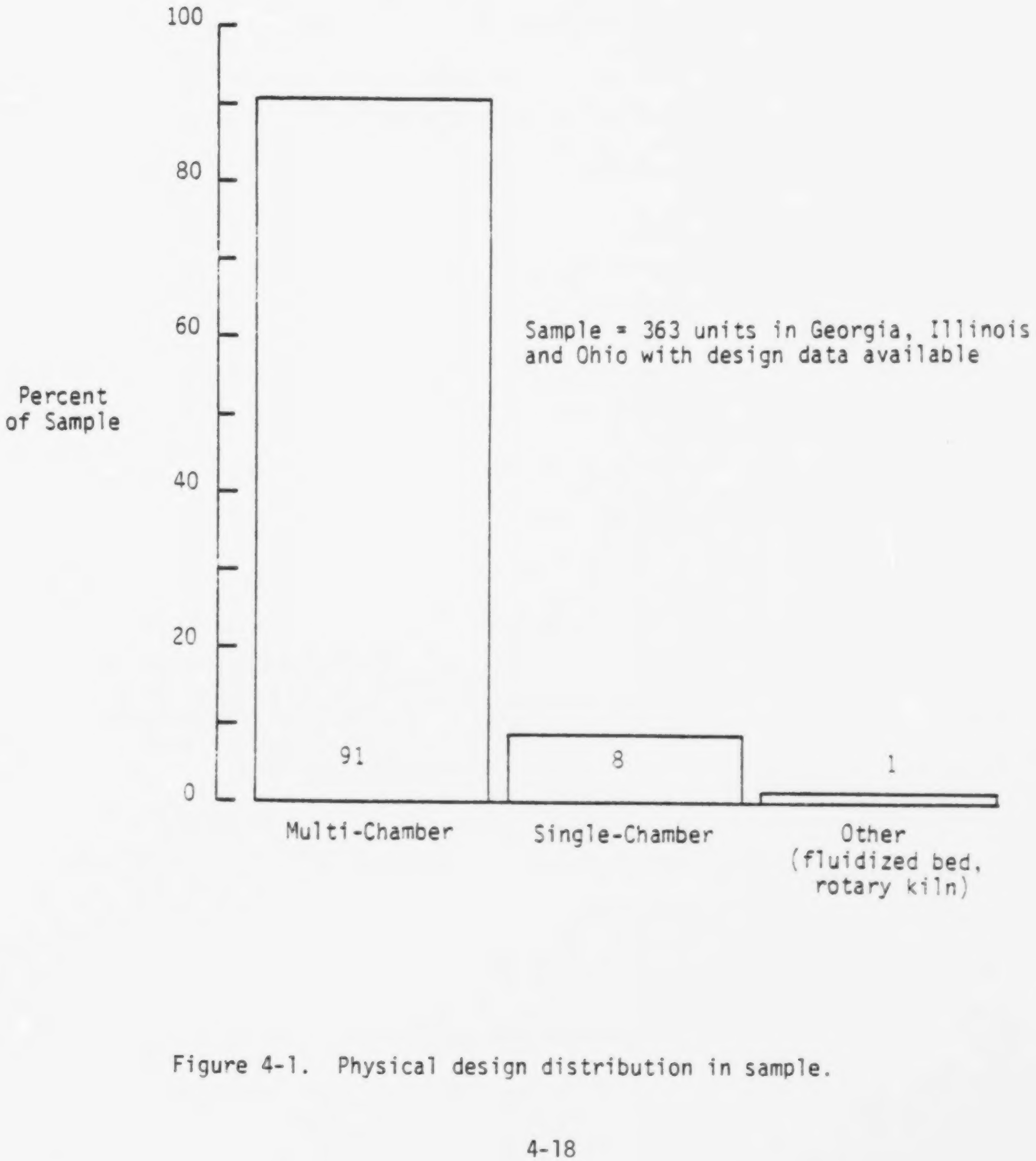
SIC code	Incinerators in sample	Capacity kg/hr (lb/hr)	
		Range	Mean
20 Food	39	9-2722 (20-6000)	294 (647)
21 Tobacco	1	N/A	907 (2000)
22 Textile	8	9-454 (20-1000)	263 (580)
23 Apparel	4	45-272 (100-600)	159 (350)
24 Lumber	8	9-2835 (20-6250)	708 (1560)
25 Furniture	8	36-862 (80-1900)	312 (688)
26 Paper	9	9-454 (20-1000)	141 (311)
27 Printing	20	27-272 (60-600)	110 (242)
28 Chemical	45	9-1279 (20-2820)	277 (610)
29 Petroleum	0	N/A	N/A
30 Rubber, plastic	11	45-644 (100-1420)	238 (524)
31 Leather	0	N/A	N/A
32 Stone, glass, and clay	5	109-261 (240-575)	208 (459)
33 Primary metal	26	9-2041 (20-4500)	74 (164)
34 Fabricated metal	49	1-907 (2-2000)	158 (349)
35 Machinery	54	18-989 (40-2180)	179 (395)
36 Electric machinery	40	9-680 (20-1500)	152 (336)
37 Transportation equipment	13	3-1361 (6-3000)	411 (904)
38 Instruments	11	45-2268 (100-5000)	308 (678)
39 Miscellaneous manufacturing	22	18-1814 (40-4000)	179 (395)
TOTAL	376	1-2835 (2-6250)	282 (621)

[a] Sample consists of incinerators in North Carolina, Georgia, Ohio and New York with capacity data.

denoted "uncontrolled" or "excess air" were classificed as natural draft units. "Uncontrolled" in this group refers to the incinerator design, not the air pollution control equipment. Units in the "other," "unknown," or "had no information given" categories were all classified as "design unknown."

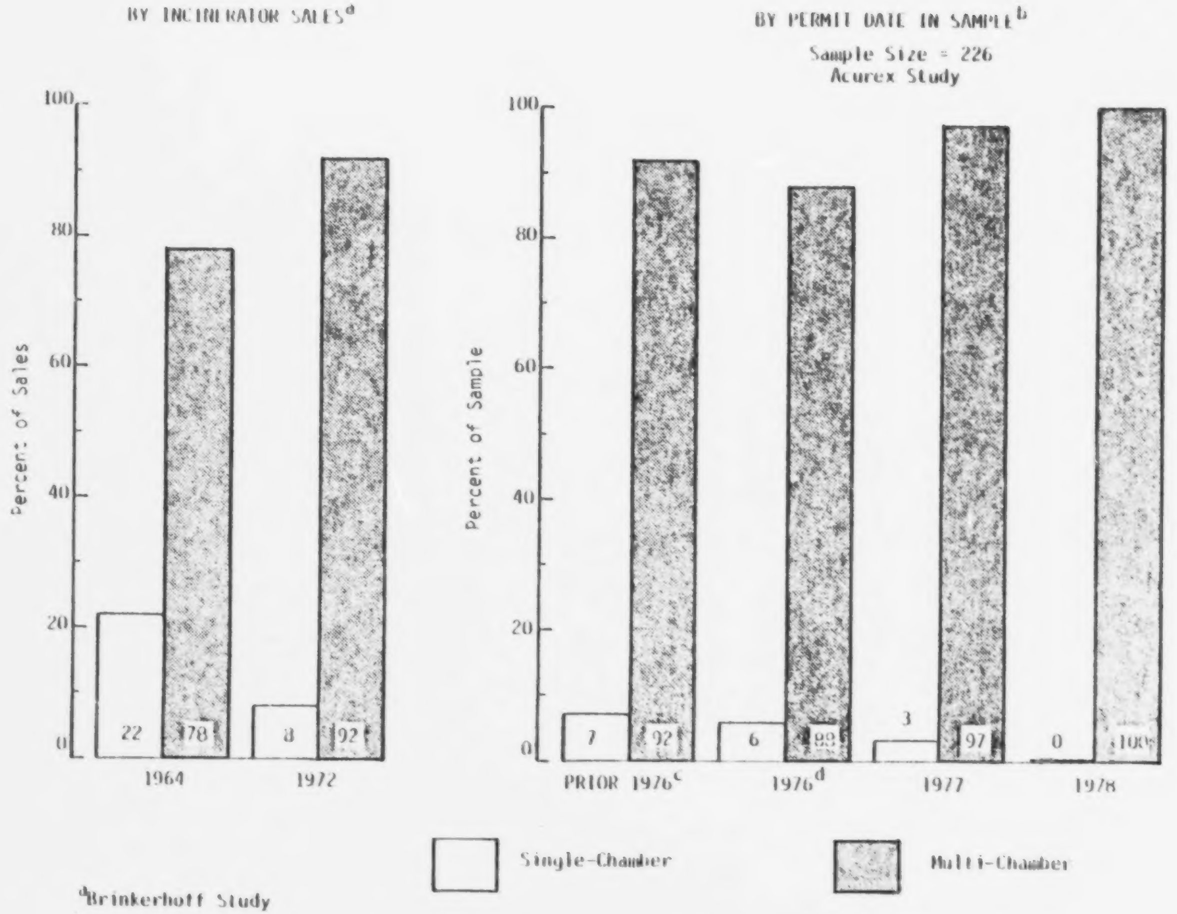
The design distribution of incinerators in the existing population is shown in Figure 4-1. The single-chamber design constituted 8 percent of the units in the sample. This percentage shows a decline from the 10 percent Brinkerhoff estimated for the 1972 population.[18] Brinkerhoff's study was based on the sales records of the Incinerator Institute of America. The drop in the fraction of single-chamber units in the population from 1972 to 1978 is substantiated by the new installation activity shown in Figure 4-2. The percentage of new single-chamber incinerators has declined steadily since 1964. There were no permits issued for single-chamber units in Georgia, Illinois, or Ohio in 1978. The capacity distribution of the single- and multi-chamber units varied only slightly, as shown in Figure 4-3. The most noticeable difference was the higher percentage of low capacity units in the single-chamber design. Both major physical design types were found in the three general use categories. The combustion air design distribution is shown in Figure 4-4. The data are given to show what had been derived from the State records; however, these data are not expected to be very reliable.

Capacity. Capacity data were generally available. When possible, capacities were derived from manufacturer's model number. If several capacities were given for a unit (which is possible because the capacity does vary with the Btu content of the waste), the highest value given was used.



A-0191

Figure 4-1. Physical design distribution in sample.



[a] Brinkerhoff Study

[b] Sample consists of incinerators in Georgia, Illinois, and Ohio with design and permit data available.

[c] Remainder of sample (1%) was conical.

[d] Remainder of sample (6%) was fluidized-bed.

Figure 4-2. Design distribution.

A-0192

A-0193

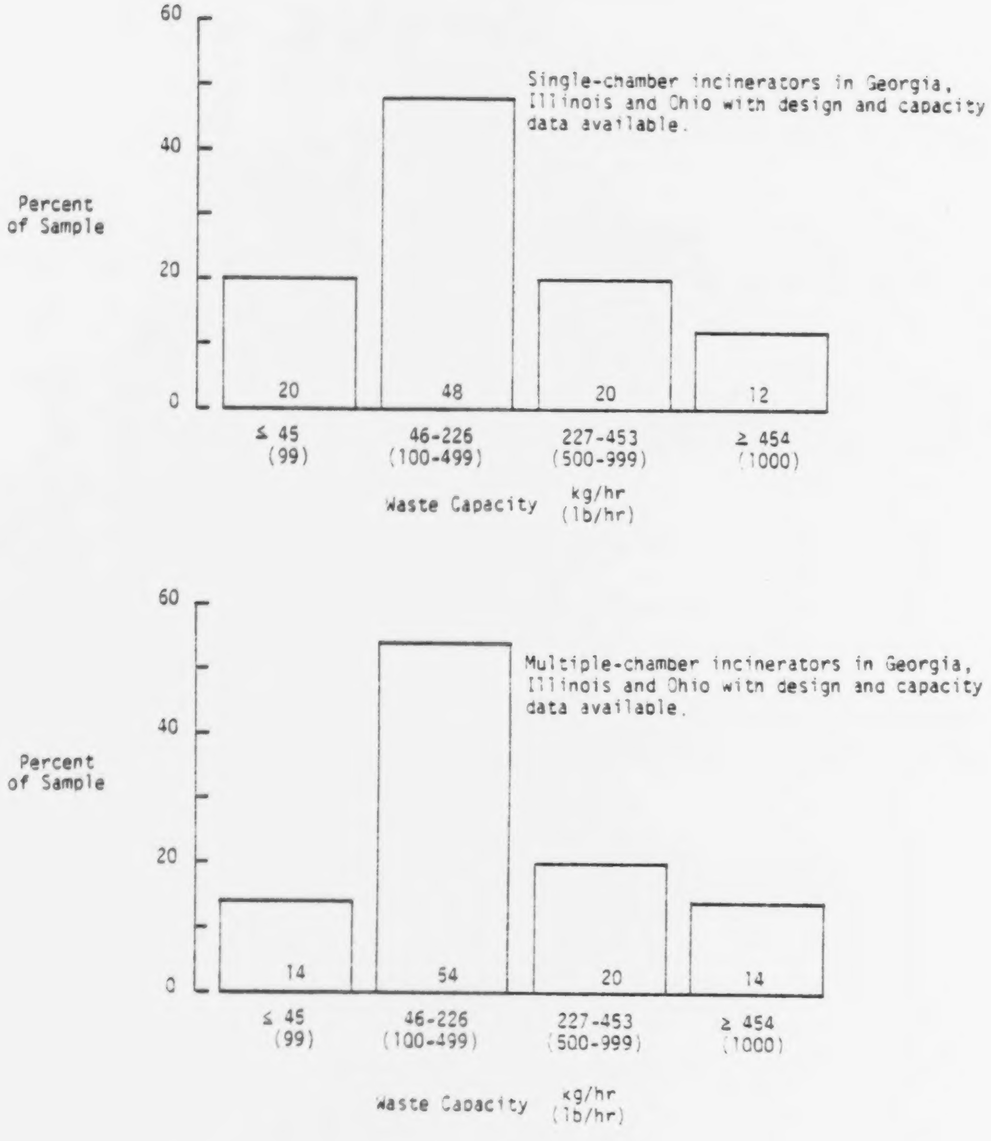
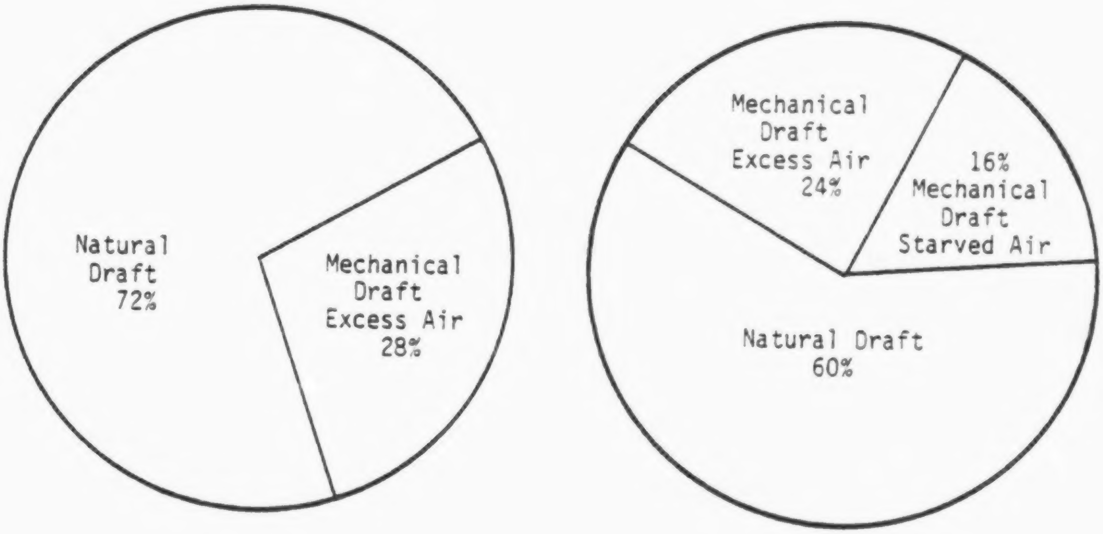


Figure 4-3. Capacity distribution by design.

A-0194



Single-Chamber
Sample Size = 14[a]

Multi-Chamber
Sample Size = 210[a]

[a] Sample consists of incinerators in Georgia, Ohio and Illinois with design data available.

Figure 4-4. Combustion air design distribution in sample.

The capacities of the units in the sample ranged from 1 to 2,835 kg/hr (2 to 6,250 lb/hr), as shown in Table 4-5. On the average, the larger units are owned by the lumber industry and the smaller units by the primary metal and printing industries. Lumber had the largest capacities even though conical units were not included in the sample. This was checked by contacting most of the lumber companies included in the sample and verifying the design of their unit. The 20 largest industrial incinerators found in the sample are listed in Table 4-6. This table includes the largest units in the six States from which listings were obtained. A more comprehensive treatment of the large industrial incinerators based upon NEDS information is given later in the report.

The capacity distribution is shown in Figure 4-5. Eighty-five percent of the units had capacities of less than 454 kg/hr (1,000 lb/hr). Units used for volume reduction had the lowest mean capacity, 210 kg/hr (462 lb/hr); those used for toxicity reduction had the highest mean capacity, 587 kg/hr (1,290 lb/hr). Waste streams handled by the smallest units included trash and pathological wastes. The largest units processed toxic solid wastes. These results are shown in Table 4-7.

Use. The waste stream descriptions available in the State records were quite vague. In order to have a reasonable amount of waste data, it was necessary to make some intuitive decisions about the type of waste. For example, wastes described as "organic," "liquid," or "hydrocarbon" were assumed to be organic hydrocarbons and were classified as Toxicity Reduction, Liquid Waste. In classifying these waste streams, the name of the company or its business activity was considered. The composition of waste streams was never assumed or guessed from the name or business activity of the

Table 4-6. TWENTY LARGEST INDUSTRIAL INCINERATORS FOUND IN MANUFACTURING INDUSTRY SAMPLE[a]

Rank	Waste capacity kg/hr (lb/hr)	SIC	State	Permit date	Design	Waste
1	2841 (6250)	24	NC	N/A	Single-chamber	Wood
2	2727 (6000)	20	IL	1974	Multi-chamber	N/A
3	2272 (5000)	20	NC	N/A	Conical	Peanut hulls
4	2272 (5000)	38	IL	1972	N/A	N/A
5	2045 (4500)	33	IL	1973	Multi-chamber	Wire
6	1818 (4000)	39	OH	1974	Multi-chamber	N/A
7	1364 (3000)	37	OH	1977	Multi-chamber	"Solid/ liquid"
8	1364 (3000)	37	NY	N/A	N/A	"Type 1"
9	1282 (2820)	28	NC	N/A	N/A	N/A
10	1282 (2820)	28	NC	N/A	N/A	N/A
11	1136 (2500)	20	NC	N/A	Conical	Peanut hulls
12	1136 (2500)	37	OH	1977	Multi-chamber	N/A
13	1136 (2500)	37	NY		Multi-chamber	"Type 2"
14	991 (2180)	35	IL	1975	N/A	N/A
15	909 (2000)	24	NC	N/A	Single-chamber	Wood
16	909 (2000)	21	NC	N/A	Multi-chamber	N/A
17	909 (2000)	20	NC	N/A	Conical	Peanut hulls
18	909 (2000)	20	IL	1973	Multi-chamber	N/A
19	909 (2000)	34	IL	1973	Multi-chamber	N/A
20	909 (2000)	20	NC	1974	Conical	Peanut hulls

[a] Sample consists of incinerators in North Carolina, Georgia, Illinois, Ohio, New York and Texas with capacity data available.

A-0195

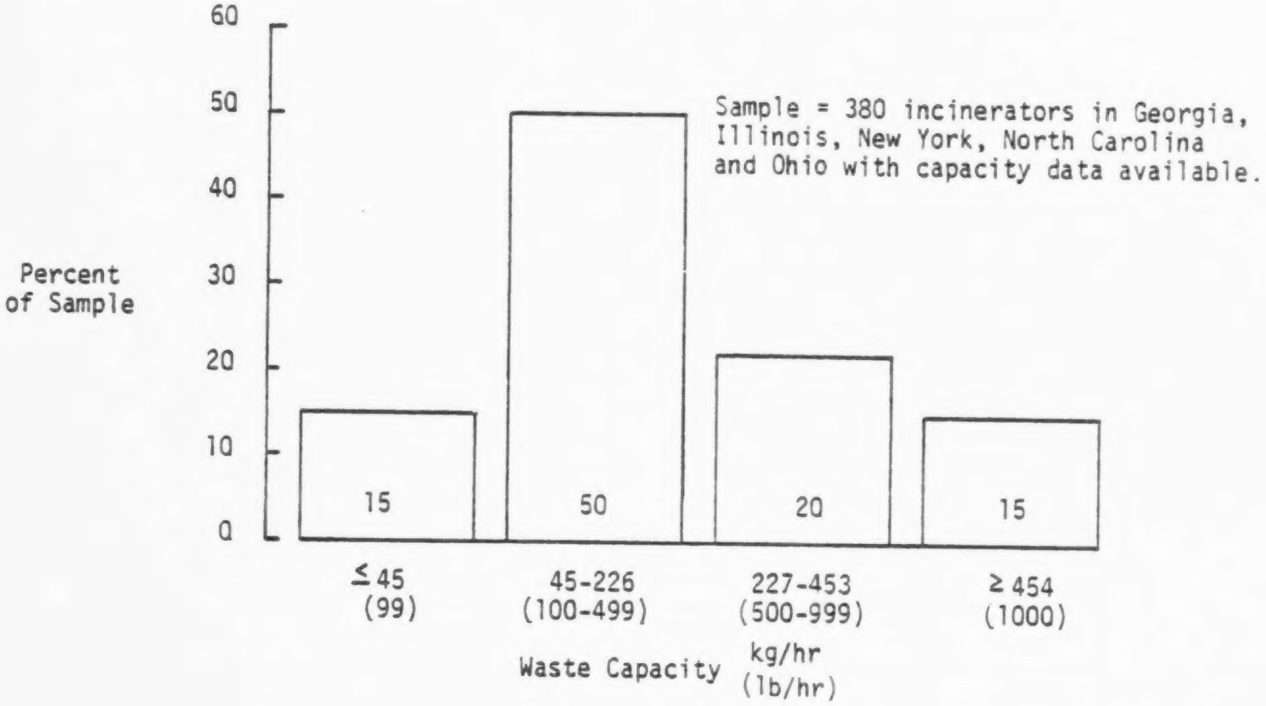


Figure 4-5. Capacity distribution in sample.

Table 4-7. CAPACITY DISTRIBUTION BY USE IN SAMPLE[a]

Primary use	Waste	Sample size	Capacity distribution kg/hr (lb/hr)	
			Range	Mean
Volume reduction	Wood	3	182-455 (400-1000)	326 (717)
	Solid	4	137-327 (300-720)	206 (455)
	Trash	13	18-409 (40-900)	172 (378)
	TOTAL	20	18-455 (40-1000)	202 (445)
Toxicity reduction	Solid	43	120-1364 (264-3000)	495 (1090)
	Liquid	5	18-681 (40-1500)	325 (716)
	Sludge	1	137 (300)	137 (300)
	TOTAL	49	18-1364 (40-3000)	368 (310)
Resource recovery	Copper wire	6	13-2045 (300-4500)	485 (1068)
	Electric motors	0	N/A	N/A
	Steel drums	2	9-764 (20-1680)	386 (850)
	X-ray film	0	N/A	N/A
	Brake shoes	0	N/A	N/A
	Other	5	1-455 (1.8-1000)	105 (232)
	TOTAL	13	1-2045 (1.8-4500)	324 (712)

[a] Sample consists of Georgia, Illinois, Ohio, and Texas with capacity and use data available.

N/A No data available.

company when no waste data were available. Additional data on the sources and types of industrial wastes are shown in Table 4-8.[19] Comprehensive use or waste data were available for Georgia only; limited data were available for Illinois. The combination of these two States provided a very small sample. Therefore, although biased toward new installations, the Texas data, which contained very comprehensive waste information, were added to the sample.

The use of each incinerator was divided into three distinct categories: volume reduction, toxicity reduction, and resource recovery. The percentages of the present population operated for these uses are shown in Figure 4-6. Volume reduction was by far the most common use. Each use category was divided into major waste streams.

The volume reduction category was divided into trash, wood, and solid industrial process waste streams. Trash included packaging, office waste, and pallets. Wood included wood waste from a furniture or lumber plant; it did not include wooden pallets. The distribution in the present population of the volume reduction category is shown in Figure 4-7.

The toxicity reduction category was divided into liquid, solid, and sludge waste streams. The distribution of the toxicity reduction category is shown in Figure 4-8. The toxic liquids were processed in 71 percent of the units in the sample; these liquids consisted entirely of organic chemicals.

The resource recovery category was divided into copper wire, electric motor, x-ray film, steel drum, brake shoe, and "other" categories. The "other" category included units used to burn off paint and those used to recover catalysts. The breakdown in the present population is shown in Figure 4-9.

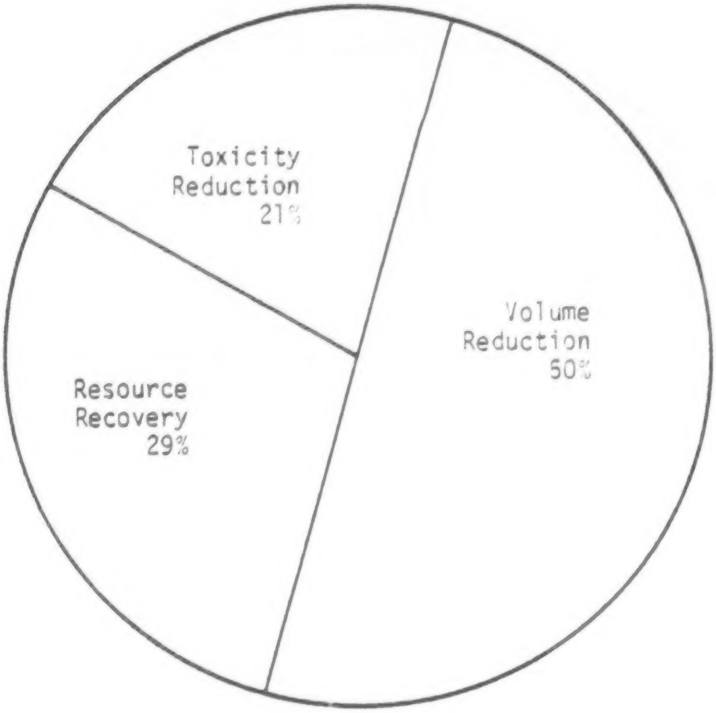
Table 4-8. SOURCES AND TYPES OF INDUSTRIAL WASTES

Code	SIC group classification	Waste generating processes	Expected specific wastes
17	Plumbing, heating, air conditioning Special trade contractors	Manufacturing and installation in homes, buildings, factories	Scrap metal from piping and duct work; rubber, paper, insulating materials, misc. construction, demolition debris
19	Ordnance and accessories	Manufacturing and assembling	Metals, plastic, rubber, paper, wood, cloth, chemical residues
20	Food and kindred products	Processing, packaging, shipping	Meats, fats, oils, bones, offal vegetables, fruits, nuts and shells, cereals
22	Textile mill products	Weaving, processing, dyeing and shipping	Cloth and fiber residues
23	Apparel and other finished products	Cutting, sewing, sizing, pressing	Cloth, fibers, metals, plastics, rubber
24	Lumber and wood products	Sawmills, mill work plants, wooden container, misc. wood products, manufacturing	Scrap wood, shavings, sawdust; in some instances metals, plastics, fibers, glues, sealers, paints solvents
25	Furniture, wood	Manufacture of household and office furniture, partitions, office and store fixtures, mattreses	Those listed under Code 24; in addition, cloth and padding residues
25	Furniture, metal	Manufacture of household and office furniture, lockers, bedsprings, frames	Metals, plastics, resins, glass, wood, rubber, adhesives, cloth, paper
26	Paper and allied products	Paper manufacture, conversion of paper and paperboard, manufacture of paperboard boxes and containers	Paper and fiber residues, chemicals, paper coatings and fillers, inks, glues, fasteners
27	Printing and publishing	Newspsper publishing, printing lithography, engraving, printing, and bookbinding	Paper, newsprint, cardboard, metals, chemicals, cloth, inks, glues
28	Chemicals and related products	Manufacture and preparation of inorganic chemicals (ranges from drugs and soups to paints and varnishes, and explosives)	Organic and inorganic chemicals, metals, plastics, rubber, glass, oils, paints, solvents, pigments
29	Petroleum refining and related industries	Manufacture of paving and roofing materials	Asphalt and tars, felts, asbestos, paper, cloth, fiber
30	Rubber and miscellaneous plastic products	Manufacture of fabricated rubber and plastic products	Scrap rubber and plastics, lampblack, curing compounds, dyes
31	Leather and leather products	Leather tanning and finishing; manufacture of leather belting and packing	Scrap leather, thread, dyes, oils, processing and curing compounds
32	Stone, clay, and glass products	Manufacture of flat glass, fabrication or forming of glass; manufacture of concrete, gypsum, and plaster products; forming and processing of stone and stone products, abrasives, asbestos, and misc. nonmineral products	Glass, cement, clay, ceramics, gypsum, asbestos, stome, paper, abrasives
33	Primary metal industries	Melting, casting, forging, drawing, rolling, forming, extruding operations	Ferrous and nonferrous metals scrap, slag, sand, cores, patterns, bonding agents
34	Fabricated metal products	Manufacture of metal cans, hand tools, general hardware, nonelectric heating apparatus, plumbing fixtures, fabricated structural products, wire, farm machinery and equipment, coating and engraving of metal	Metals, ceramics, sand, slag, scale, coatings, solvents, lubricants, pickling liquors

(continued)

Table 4-8. (continued)

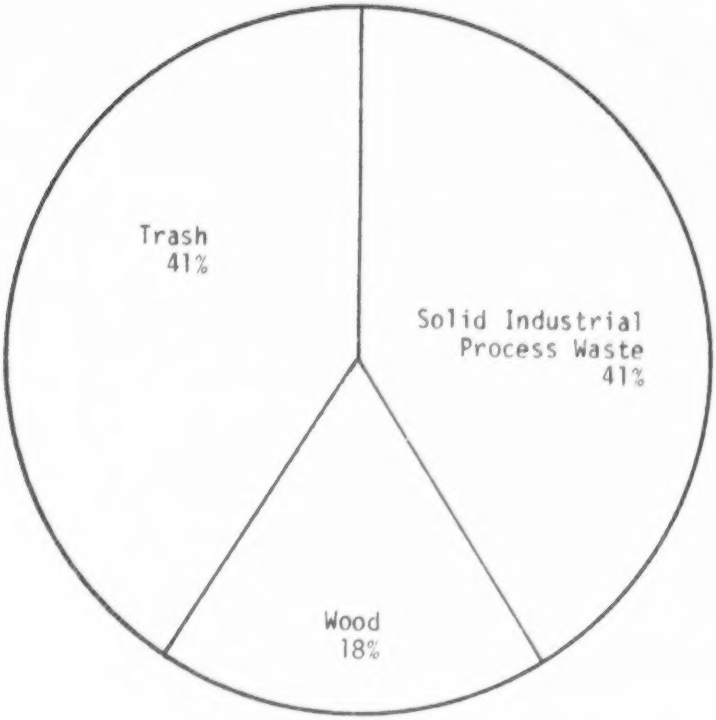
Code	SIC group classification	Waste generating processes	Expected specific wastes
35	Machinery (except electrical)	Manufacture of equipment for construction, mining, elevators, moving stairways, conveyors, industrial trucks, trailers, stackers, machine tools, etc.	Slag, sand, cores, metal scrap, wood, plastics, resins, rubber, cloth, paints, solvents, petroleum products
36	Electrical	Manufacture of electric equipment, appliances, and communication apparatus, machining, drawing, forming, welding, stamping, winding, painting, plating, baking, firing, operations	Metal scrap, carbon, glass, exotic metals, rubber, plastics, resins, fibers, cloth residues
37	Transportation equipment	Manufacture of motor vehicles, truck and bus bodies, motor vehicle parts and accessories, aircraft and parts, ship and boat building and repairing motorcycles and bicycles and parts, etc.	Metal scrap, glass, fiber, wood, rubber, plastics, cloth, paints, solvents, petroleum products
38	Professional, scientific controlling instruments	Manufacture of engineering, laboratory, and research instruments and associated equipment	Metals, plastics, resins, glass, wood, rubber, fibers, abrasives
39	Miscellaneous manufacturing	Manufacture of jewelry, silverware, plated ware, toys, amusement, sporting and athletic goods, costume novelties, buttons, brooms, brushes, signs, advertising displays	Metals, glass, plastics, resins, leather, rubber, composition, bone, cloth, straw, adhesives, paints, solvents



Sample = 97 incinerators in Georgia, Illinois and Texas with use data available.

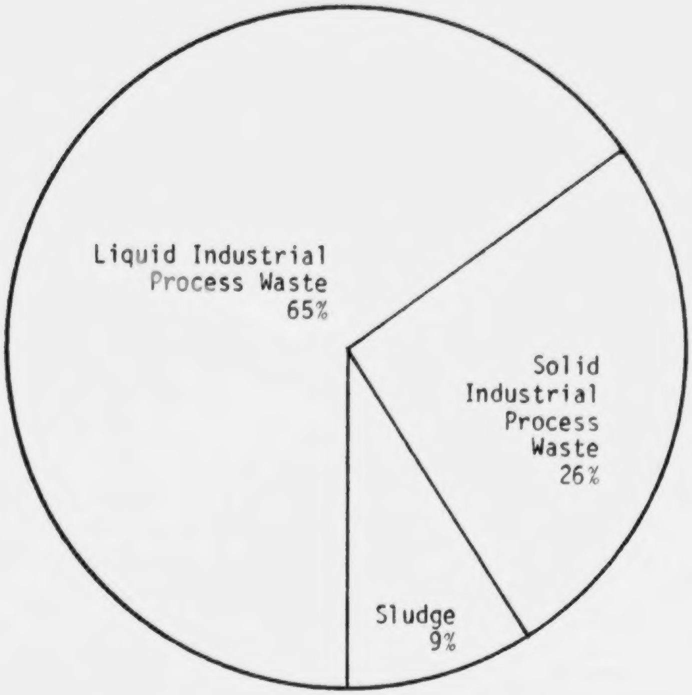
Figure 4-6. Use distribution in sample.

A-0197



Sample = 46 incinerators in Georgia, Illinois and Texas with waste data available.

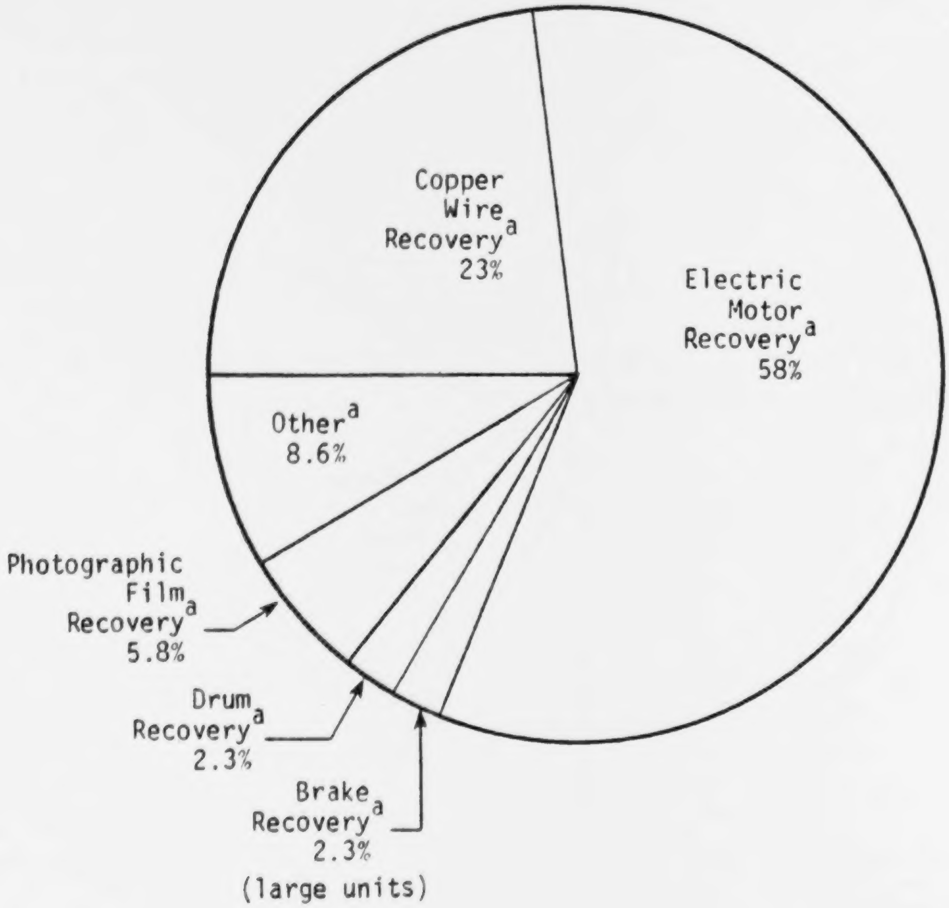
Figure 4-7. Waste distribution in sample of the volume reduction category.



Sample = 23 incinerators in Georgia, Illinois and Texas with waste data available.

Figure 4-8. Waste distribution in sample of the toxicity reduction category.

A-0199



[a] Based on supplemental data collected for all subcategories except "other" which is based upon a sample consisting of incinerators in Georgia, Illinois and Texas with waste data available.

Figure 4-9. Waste distribution in resource recovery category.

The breakdown shown in Figure 4-9 for all the subcategories except "other" is based upon the supplemental data collected on resource recovery units rather than a statistical breakdown of the sample. The "other" subcategory was based on the sample.

- Wire Incinerators. The existing wire incinerator population is estimated to be 200-400 units. Since there are no national statistics on the population of these units, this estimate is based upon sales data collected from manufacturers. Two firms sell wire incineration equipment. One has sold nine units in the last 10 years. The other firm estimates it has sold 400 units over the last 9 years. The latter firm is believed to account for all sales of wire units today.[20] Although a year-by-year estimate of sales would not be provided, data collected from incinerator operators, air pollution control agencies, and trade associations seem to indicate that a large proportion of the 400 units was sold in the early part of the 9-year period. In addition, a significant fraction of the 400 units is assumed to no longer be in service. The existing population estimate reflects these assumptions.

- Motor Incinerators. The population of motor incinerators is estimated at 800-1,000 units nationally.[17] The units are typically owned by small electric motor repair shops with 5-10 employees. The typical unit processes about 400-500 pounds of motors per day, with approximately 2 percent of this weight being combustibles.[21] This amount is usually well below the capacity of the unit because the owners do not normally stockpile motors. Their objective is to incinerate motors as soon as they receive them in order to repair them quickly for their customers.

- X-ray Film Incinerators. The population of x-ray film incinerators is estimated at 100 units nationally.[22,23]

- Steel Drum Incinerators. The population of steel drum incinerators is estimated at 39 units according to the study released by the Industrial Environmental Research Laboratory (IERL), April 1978.[24]

- Brake Shoe Incinerators. Remanufacturers of drum brakes range in production from a small firm that processes only 200 brakes per month to a large one that processes 250,000 brakes over the same time period.[25] The small operation typically relies on a small package incinerator that utilizes a 55-gallon steel drum as its primary chamber. The units are sold with an afterburner in the stack as standard equipment.[26] No estimate was available on how many units are in the existing population, but it is suspected that they number in the hundreds. The large unit typically processes 200-250 brakes/hour in either a batch or continuous operation.[27] The population is estimated at 30-40 units.[28]

Equipment Utilization. The mean number of hours the incinerators in each major waste stream classification operate each year is shown in Table 4-9. The units used for volume reduction have the lowest annual use rate, 2,820 hours or approximately one 8-hour shift every day of the year. The lowest mean was 867 hours for units used to reduce the volume of trash, while the highest mean was 7,305 hours or nearly three 8-hour shifts every working day. This highest value represented the units used for toxicity reduction.

Size of the Manufacturing Population Excluding Conicals. The projected size of the manufacturing population excluding conicals is 3,800 units. This value was calculated by summing projected populations for each of the

Table 4-9. EQUIPMENT UTILIZATION DISTRIBUTION BY INCINERATOR USE IN SAMPLE[a]

Use	Waste stream	Sample size	Hours of annual operation
Volume reduction	Solid	22	3941
	Wood	5	3016
	Trash	19	867
	TOTAL Volume reduction	46	2510
Toxicity reduction	Solid	5	5891
	Liquid	15	7834
	Sludge	2	8568
	TOTAL Toxicity reduction	22	7480
Resource recovery	Wire	12	3412
	Motors	6	1071
	Film	3	3107
	Drums	1	2080
	Brakes	2	5448
	Other	4	5434
	TOTAL Resource recovery	28	3264

[a] Sample consists of incinerators in Georgia, Illinois, and Texas with annual operation and use data.

three use categories. Two different methods were used to derive the number of units in each use category. The estimate for the volume and toxicity reduction categories was based on the sample, since it is believed that those categories are adequately represented in the sample. The values were derived from the preliminary population estimate in Table 4-3 and the use distributions shown in Figures 4-6 through 4-8. The units used for resource recovery are not believed to be adequately represented in the sample because of the underrepresentation of electric motor and brake shoe units which are typically small in capacity. Therefore, the number of units in the resource recovery category was based on supplemental data collected on the number of units processing each waste stream. This was done for all the resource recovery waste streams except "other" which was extrapolated from the sample. The population segments and sizes presented in Table 4-10 will be used in Section 5 and later in this section to determine current and future nationwide emissions and the future population.

4.1.4 Conical Wood Incinerators

In a 1974 study by Battelle, the total number of active conicals in 1978 was estimated at 490.[29] This number was based on a survey done in five States (California, Georgia, Louisiana, Oregon, and Washington) in 1973. Battelle assumed the number of conicals in the rest of the United States to be 50 percent of the number in the five States surveyed, and estimated the total number of conicals in the United States in 1973 at 835. The national conical incinerator population in 1978 was derived based on growth trends in conicals in Oregon and California between 1968 and 1973.

4.1.5 Off-site Incineration

Off-site incineration is practiced by private waste disposal firms which centrally process the waste stream of many establishments. Industry

Table 4-10. MANUFACTURING SEGMENT OF THE NATIONAL INDUSTRIAL INCINERATOR POPULATION BY USE CATEGORY

Use	Waste stream	Units in nation
Volume reduction	Solid industrial process	620
	Wood	260
	Trash	620
	TOTAL Volume reduction	1500
Toxicity reduction	Solid industrial process	170
	Liquid industrial process	420
	Sludge	50
	TOTAL Toxicity reduction	640
Resource recovery[a]	Copper wire	400
	Electric motors	1000
	X-ray film	100
	Steel drums	40
	Brake shoes	40
	Other	130
	TOTAL Resource recovery	1700[b]
TOTAL POPULATION		3800[a]

[a] Population figures given are maximums of expected range.

[b] This figure does not equal the sum of its components because it is rounded to 2 significant figures.

generates about 35 million megagrams of hazardous residues yearly, approximately 80 percent of which is disposed of on site while the remaining 20 percent is shipped to private waste handlers.[30] The private firms operate about 100 hazardous waste sites, which have a total capacity (as of 1976) of 7.3 million megagrams/year. It is estimated that these firms utilize fewer than 10 incinerators.[31] The bulk of the waste is disposed of by landfill, deep well injection, and land farming.

Approximately half the wastes generated by industry cannot be incinerated.[31] Either these substances are noncombustible or they contain toxic elements such as arsenic or lead that would be released to the atmosphere. In order to provide their customers with a complete waste disposal service, private firms offer several disposal alternatives. Land disposal techniques provide the most versatility at this time. Firms that incinerate wastes must rely on land techniques for the ultimate disposal of the residues. When incinerators are used by these firms, rotary kilns are commonly employed because of their high capacities and versatility. Rotary kilns can handle liquids, solids, gases, and sludges, including some of the containers in which these wastes are shipped.

Off-site incineration offers several advantages over on-site processing. Generally, larger quantities of waste are processed, allowing the owner to take advantage of some economies of scale resulting in lower incineration costs per pound of waste. Because off-site incineration involves wastes from several sources, off-site operations enable blending of wastes to control the Btu content. Such blending decreases the need for auxiliary fuel. Because off-site units generally operate 24 hours a day, the emissions and maintenance problems associated with startup are minimized.

An example of an off-site incinerator owner is Rollins Environmental Services. Rollins is the largest private disposal firm that specializes in handling hydrocarbon wastes at disposal facilities in Bridgeport, New Jersey; Baton Rouge, Louisiana; and Houston, Texas. These plants serve customers in 32 States. Each Rollins plant maintains facilities for the treatment of wastes utilizing thermal, chemical, and biological treatment systems. Since 1969, Rollins estimates they have handled 10,000 different wastes.[32]

The incineration system at Rollins' Houston facility consists of a rotary kiln and a liquid injection system, both feeding a common afterburner. The system is shown in Figure 4-10. The main burner is for liquid wastes only and is of the vortex horizontal type. The waste liquid burner flame temperature is approximately 1500°C. Flame temperature in the kiln is normally 1300°C. Afterburner temperature is typically 1300°C. Overall retention time of the incinerator and afterburner is from two to three seconds at an average temperature of 1400°C. The total heat release rate is 100 GJ/hr (95 x 10^6 Btu/hr). Solid wastes, usually packed in fiber drums, are fed into the rotary kiln by a conveyor. Liquids and sludges may also be pumped into the kiln. Liquid wastes that can be burned in the waste liquid burner are fed directly from tanks into the burner. Both the kiln and the waste liquid burner are equipped with natural gas igniters and gas burners for initial refractory heatup, flame stability, and supplemental heat, if necessary. Supplemental heat can also be provided by burning No. 2 fuel oil. As shown in Figure 4-10, the effluent gases from the incinerator are passed through a duct into a wet venturi scrubber, absorption trays, and a mist eliminator before entering the stack. The exhaust stack is

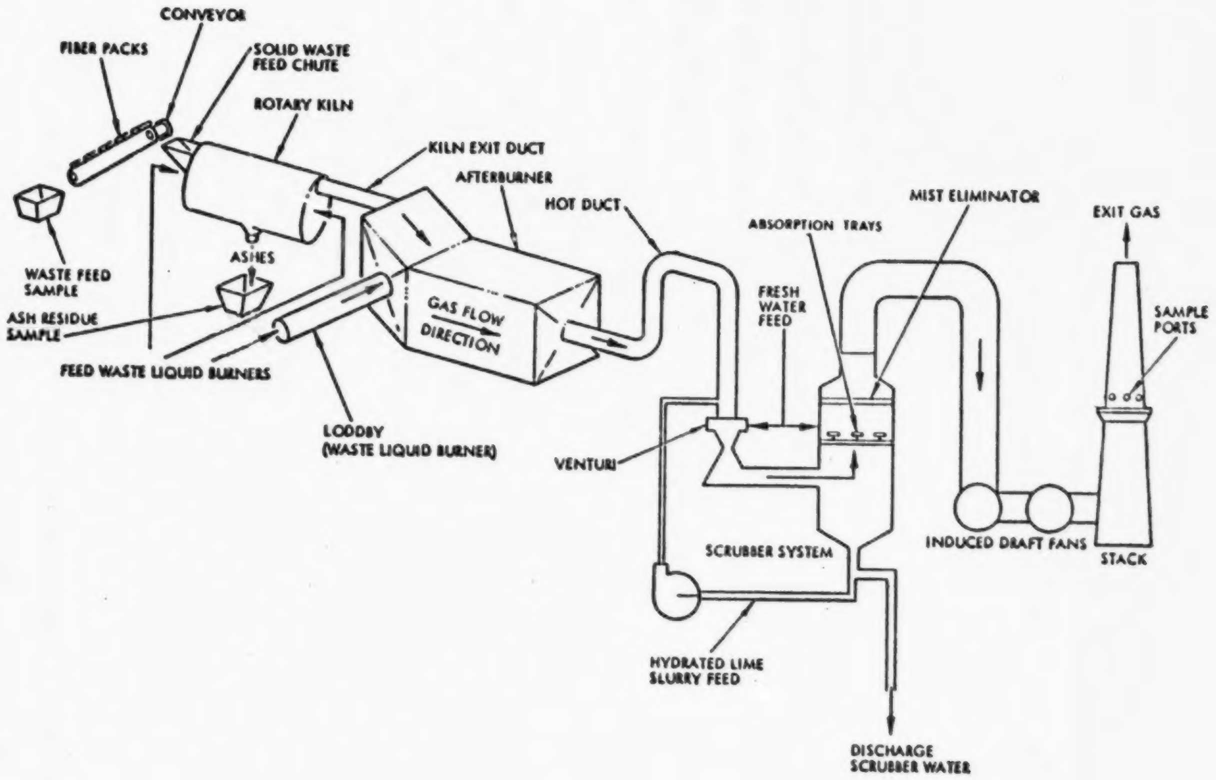

CONVEYOR
FIBER PACKS
SOLID WASTE FEED CHUTE
ROTARY KILN
KILN EXIT DUCT
AFTERBURNER
HOT DUCT
MIST ELIMINATOR
ABSORPTION TRAYS
EXIT GAS
SAMPLE PORTS
WASTE FEED SAMPLE
ASHES
ASH RESIDUE SAMPLE
GAS FLOW DIRECTION
FRESH WATER FEED
FEED WASTE LIQUID BURNERS
LODDBY (WASTE LIQUID BURNER)
VENTURI
SCRUBBER SYSTEM
INDUCED DRAFT FANS
STACK
HYDRATED LIME SLURRY FEED
DISCHARGE SCRUBBER WATER

Figure 4-10. Schematic of Rollins Environmental Services incinerator.

30 meters high. Lime is used in the absorbent to neutralize the acid gases from the gas stream. Used absorbent, typically containing 10,000 ppm calcium and 10,000 ppm chlorides, is discharged into settling ponds where it is analyzed and further treated, if necessary, before final discharge.[33]

4.1.6 Major Sources

This section enumerates industrial incinerators that are major sources. A major source is one that has the potential to emit over 100 tons of a criteria pollutant per year. Table 4-6 listed the 20 largest incinerators in the six States from which data were obtained. Only two of these are major sources.

Unlike incinerators in general, major sources must be reported to the NEDS information base. Assuming that the NEDS data are complete, the records will produce a listing of all the major industrial incinerators in the nation. A listing was requested from NADB of all the emission points in the NEDS described by an SCC beginning with "5" (incinerators) and emitting 99 tons or more of a criteria pollutant per year.

The NEDS listed the potential emissions for each emission point it contained. This information was not available for the data collected by sampling. Therefore, in order to determine if any major sources were found in the sample, it was necessary to estimate the potential emissions of the incinerators by using the AP-42 emission factors.[34] The factors used are presented in Table 4-11. The factor in the table for conical units is the one given in AP-42 for unsatisfactory operation. This factor was used because generally the operation of conical units is described by State air pollution officials as unsatisfactory.

Table 4-11. EMISSION FACTORS FOR REFUSE INCINERATORS WITHOUT CONTROLS[a]

Incinerator type	Particulates		Sulfur oxides[b]		Carbon monoxide		Hydrocarbons[c]		Nitrogen oxides[d]	
	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg
Industrial/commercial										
Multiple chamber	7	3.5	2.5	1.25	10	5	3	1.5	3	1.5
Single chamber	15	7.5	2.5	1.25	20	10	15	7.5	2	1
Conical[e]	7	3.5	0.1	0.05	130	65	11	5.5	1	0.5

[a] Average factors given based on EPA procedures for incinerator stack testing.

[b] Expressed as sulfur dioxide.

[c] Expressed as methane.

[d] Expressed as nitrogen dioxide.

[e] Factor is for wood waste assuming unsatisfactory operation.

The major sources found in the NEDS and in the sample are presented in Table 4-12. Conical incinerators that burned wood were excluded from the sample as well as from the compilation of the NEDS.

4.1.7 Other Incinerator Groups

Data have been collected on several incinerator groups that are not strictly defined as industrial units but do have many similarities to such units. They have been briefly examined because they are not presently subject to a new source performance standard (NSPS) and, due to the similarities, it might be reasonable to include them in the industrial incinerator source category.

Cotton Gin Waste. Cotton gin waste is burned in a specialized single-chamber incinerator called a jug incinerator. These units are used for the disposal of burrs and trash generated from cotton ginning. Incinerators are operated during the harvesting season which lasts 6 to 8 weeks. Operation of jug incinerators produces emissions that have resulted in a continual enforcement problem for State agencies. In Texas and California, jug incinerators have been successfully phased out in favor of alternative means of disposing of cotton ginning wastes, such as composting and land filling. In other States, large smoke emissions from these units can be seen billowing plumes many miles in length.[35]

A modified jug incinerator is shown schematically in Figure 4-11. The incinerator, a hearth-type unit without grates, is equipped with an afterburner assembly to control emissions of particulates and smoke. The combustion chamber consists of a brick-lined cylindrical section and a cone-shaped roof. Burrs and screened trash are blown into the incinerator through a cyclone collector located on the roof. All of the combustion air is supplied

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Table 4-12. MAJOR SOURCES

SIC code	Owner	State	Emissions, megagrams/year (tons/year)					Air pollution controls	Efficiency	Design	Data source
			PM	SO_2	NO_x	HC	CO				
29 Petroleum	Continental Oil Co.	LA	410 (451)	1100 (1210)	134 (147)	5 (6)	4 (4)	Centrifugal collector	91%		NEDS
28 Chemical	Kaiser Agricultural	FL	357 (393)							Multi-chamber	NEDS
28 Chemical	Pitt Consolidated Chemical	NJ	188 (207)	27 (30)	81 (89)	81 (89)	268 (295)			Multi-chamber	NEDS
24 Lumber	Futrell Lumber	NC	186 (205)							Single-chamber	Sample
49 Disposal	Liquid Waste Disposal	MI	184 (203)	8 (9)						Liquid	NEDS
20 Food	Gilliam Brothers Peanut Shellers	NC	149 (164)							Conical	Sample
Unknown	Mateo	NJ	141 (155)								NEDS
28 Chemical	Dow Badische	TX	140 (154)	855 (941)	50 (55)		1 (1)				NEDS
28 Chemical	Dow Badische	TX	140 (154)	855 (941)	50 (55)		1 (1)				NEDS
49 Disposal	Rollins	NJ	130 (143)	102 (113)	22 (24)	22 (24)	75 (80)	Wet scrubber	87% PM 50% SO_2	Multi-chamber	NEDS
28 Chemical	Pitt Consolidated Chemical	NJ	130 (140)	45 (50)	55 (60)	55 (60)	181 (200)			Multi-chamber	NEDS
49 Disposal	Rollins	TX	116 (128)	393 (433)	2 (2)			Wet scrubber	85% PM		NEDS
Unknown	Tennessee Eastman	TN	100 (110)	2 (2)	4 (4)	4 (4)	14 (15)	Wet scrubber	99.5% PM	Rotary kiln	NEDS
28 Chemical	3-M	MN	100 (110)	36 (40)	19 (21)	19 (21)	64 (70)	Venturi	95% PM 50% SO_2	Multi-chamber	NEDS
30 Rubber	UniRoyal	CN		1173 (1290)							NEDS
Unknown	3-M	IL	83 (91)	567 (624)	289 (318)	64 (12)	1 (1)			Single-chamber	NEDS
Unknown	S. C. Johnson	WI		683 (751)	455 (500)						NEDS
28 Chemical	Mobile Chemical	TN			455 (500)						NEDS
28 Chemical	Union Carbide	TX	7 (8)		103 (113)	2 (2)	3 (3)			Liquid	NEDS
TOTAL			2560 (2816)	5235 (5758)	1716 (1888)	198 (218)	609 (670)				

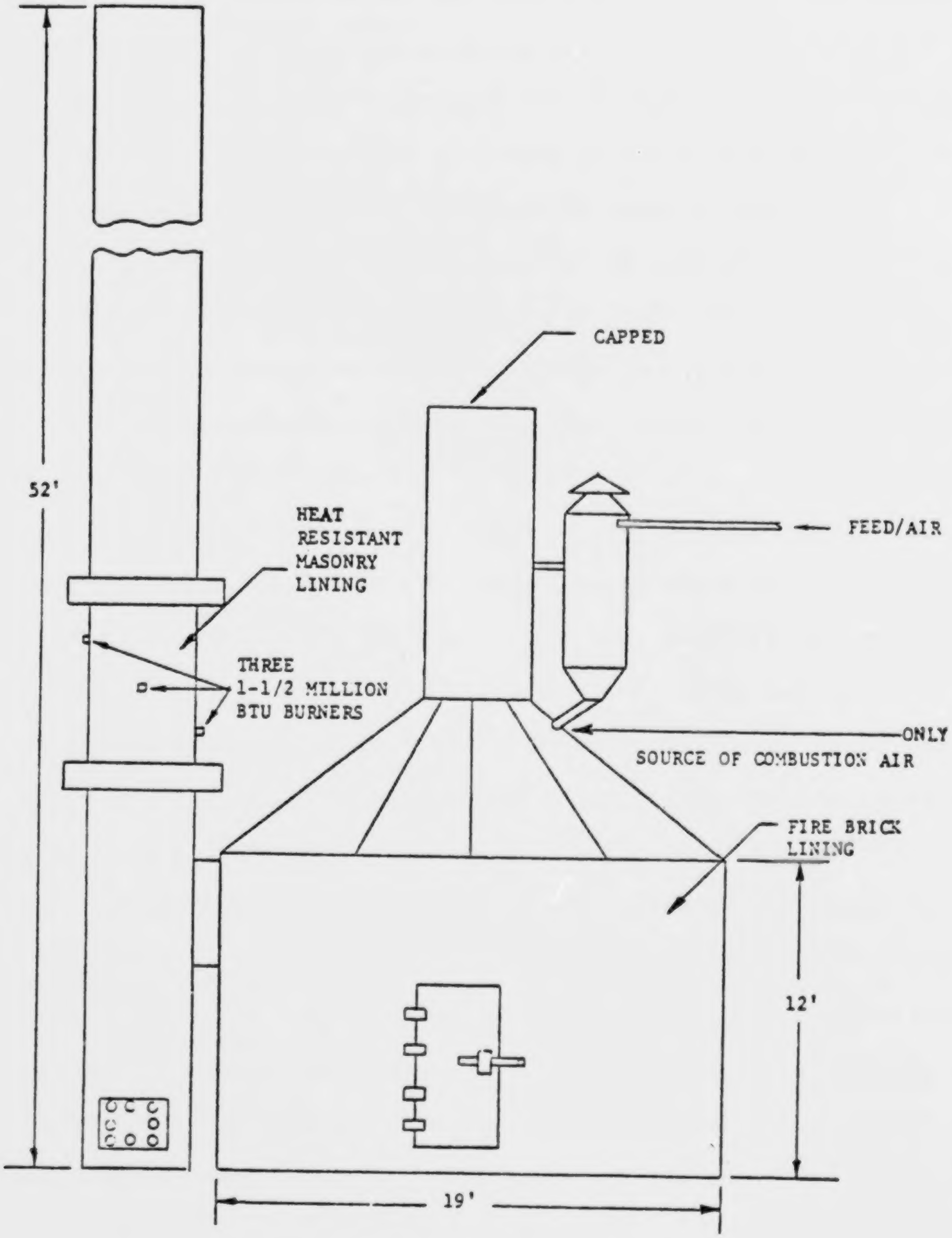

CAPPED
FEED/AIR
52'
HEAT RESISTANT MASONRY LINING
THREE 1-1/2 MILLION BTU BURNERS
ONLY SOURCE OF COMBUSTION AIR
FIRE BRICK LINING
12'
19'

Figure 4-11. Modified jug incinerator.

with the feed. Three 1.5 x 10^6 Btu burners are used as afterburners; one is operated continuously, and the other two are thermostatically controlled.

In a 1974 Battelle study, the annual production of cotton was estimated at 13 million bales per year.[36] The quantity of wastes generated from cotton ginning depends on the method of harvesting employed. Machine picking, for example, produces 40 kg (89 lb) wastes/bale, and machine stripping produces 350 kg (776 lb) wastes/bale. For the purpose of estimating waste generation rates, it was assumed by the authors of the Battelle study that 75 percent of the harvesting is done by machine picking and the remainder is done by machine stripping. Based on this assumption, the total waste generation for 1978 is 1.6 million megagrams (1.7 million tons) per year. It was estimated in the Battelle study that there are 712 jug incinerators in the existing population, with estimated particulate emissions of 820 megagrams (900 tons) per year. There are six cotton gins in the United States that recover process heat from cotton gin waste.[37] These units can meet 100 percent of the heat requirements of ginning operations. Development of these gins is still in the experimental stage. Difficulty in controlling emissions and the energy economics that favor the use of natural gas are two major barriers to widespread use of these units. The existing units generally are operating under a variance from State agencies because they are classified as innovative technology.

Peanut Hulls. Peanut hulls are not commonly incinerated because they serve several valuable purposes. Peanut hulls are used in cattle feed, mulch, mushroom production, activated charcoal, brick, domestic cat litter, and fiberboard manufacture, and as an oil slick absorbent.[38] Some incineration was reported in North Carolina and in a waste-fired boiler in

Georgia which operates a 20,000 pound steam boiler fired with hulls. The latter facility is a food processing plant that uses the heat in peanut roasters and candy-making processes.[39]

Rice Hulls, Walnuts. Alternate uses for rice hulls, primarily as a chemical feed and as a low-cost landfill, generally preclude incineration. A waste-fired boiler at a rice mill in Texas meets 100 percent of its energy demands with rice hulls.[40] In Arkansas a rice company formerly incinerated rice hulls to recover a silica abrasive from the ash. The ash wore out the incinerator, bringing the experimental operation to an end. According to NEDS data, an establishment in Kansas incinerates "green" walnut waste in a conical incinerator.

4.2 TRENDS AND ESTIMATES OF FUTURE POPULATION

This section includes a discussion of factors that may affect the size of the industrial incinerator population. These factors, in light of the growth trends found in the states that were sampled, are used to project the 1983 industrial incinerator population.

4.2.1 Factors Affecting Growth

Industrial incinerator growth is affected by energy costs, incentives to recycle solid wastes and government regulations. An in-depth study of the interactions of these factors, their cost tradeoffs and their relationships to specific sites and wastes could not be completed within the time frame of this study. What follows is a qualitative discussion of these factors and how they will influence new installation activity.

Resource Conservation and Recovery Act (RCRA). The Resource Conservation and Recovery Act of 1976 (RCRA), 42 USC 6901, is the first comprehensive regulation of solid waste. The objectives of RCRA include insuring the environmentally safe disposal of both hazardous and non-hazardous wastes while promoting resource conservation and the recovery of materials and energy from solid waste. With respect to industrial incinerators, the areas of major interest are Subtitle D, the regulations for the land disposal of waste that is not hazardous, and Subtitle C, the regulations for hazardous waste management.

Land disposal of non-hazardous wastes will be regulated by the States with certain Federally imposed constraints. Subtitle D mandates that all open dumps will be either upgraded to a sanitary landfill or closed. All disposal is required to be in a sanitary landfill. This mandate will raise the cost of land disposal. Generally, the economics of land disposal versus incineration favor land disposal at this time. Even though the results of Subtitle D may raise landfilling costs significantly, a shift of the economic balance to the point where incineration will become the cheaper alternative is not expected.

Subtitle C, the hazardous waste management provisions, is more detailed than Subtitle D and provides the greater degree of regulation necessitated by the properties of hazardous wastes. Subtitle C provides for the "cradle to grave" regulation of the wastes as well as an identification and listing of hazardous wastes according to specified criteria. Rules under Subtitle C were proposed in the FEDERAL REGISTER on December 18, 1978. Public hearings were held in early 1979. Final promulgation is expected in late 1979 or early 1980.

The sections of Subtitle C that have particular relevance to growth trends in the incinerator population are Sections 3002 and 3004. Section 3002 requires all who handle hazardous waste to comply with a manifest system, to ensure that the wastes are transported from the waste generator to an acceptable disposal facility. The manifest is a special form of shipping paper that is filled out by the waste generator. It directs and tracks the movement of the wastes from the point of generation to ultimate disposal. This comprehensive tracking system will increase the costs involved in offsite disposal and may promote onsite disposal. For firms with inappropriate waste or insufficient land, the onsite alternatives would include incineration, use as a fuel, or recycling. For other firms, onsite landfilling may be the most feasible alternative. A precise estimate of which of these options will be selected is difficult to make because a firm's actions will be highly waste- and site-specific. Factors that will influence the decision will include the combustibility of the waste, the energy needs and cofiring capability of the company, the recycling potential of the waste, and the willingness of the company to monitor and maintain a landfill for a period of 20 years after facility closure. Generally, Section 3002 is expected to provide a moderate incentive for growth in the population of units used for incineration of toxic substances, but these positive incentives may be outweighed by the negative one in Section 3004.

Section 3004 contains standards of performance for those who store, treat, or dispose of hazardous waste. This section dictates how a hazardous waste landfill should be located, designed, constructed, and operated to prevent direct contact between the landfill and water resources. These requirements alone would mean the section promotes incinerator growth. However, the section also requires stringent standards of performance for incinerators. The incinerator regulations require trial burns for each significantly different waste, continuous monitoring for CO and O_2, and a combustion efficiency of 99.9 percent. Units are also required to have automatic controls that will shut off the device in the event of a system malfunction. A 99.99 percent destruction efficiency is required. The maximum allowable emissions are 0.08 grains per dry standard cubic foot corrected to 12 percent carbon dioxide (CO_2). In addition, an incinerator used to degrade a hazardous waste containing more than 0.5 percent halogens must be equipped with emission control equipment capable of removing 99 percent of the halogens from the exhaust gases.

Section 3004 will increase the cost of incinerating and landfilling hazardous waste. This will result in a new set of cost tradeoffs between the two waste processing techniques. The technique that will be favored will be site- and waste-specific. Generally, landfilling is expected to remain as the favored disposal method.

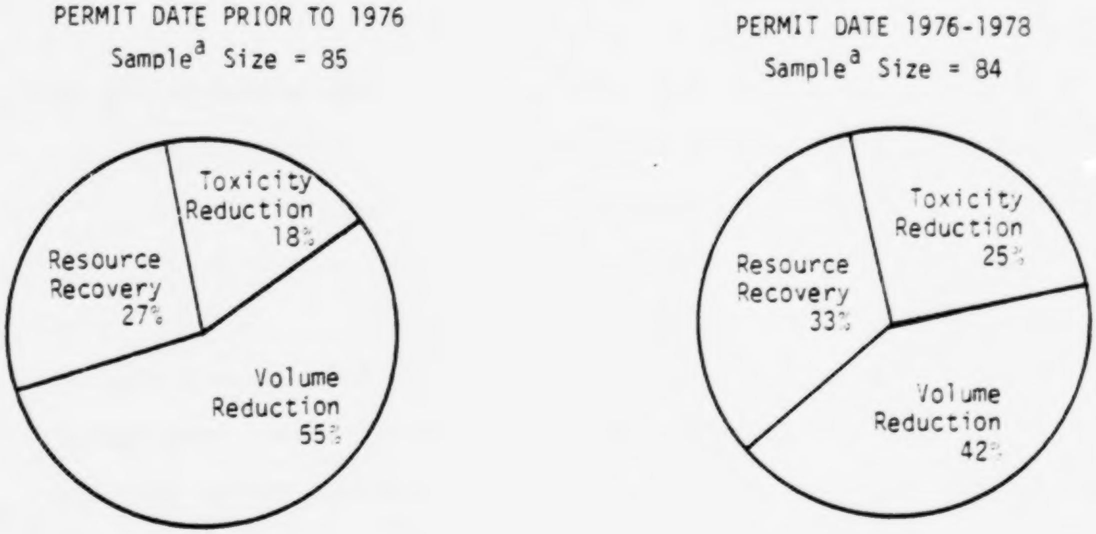
As initially written, RCRA creates some major barriers to burning hazardous waste in industrial boilers. The residence time of 2 seconds and the combustion temperatures of 1200°C for halogenated aromatics and 1000°C for other hazardous wastes preclude the use of boilers. However, within Section 6002 of the Act are requirements that Federal agencies using fossil fuel as a primary or supplementary fuel in systems that have the technical capability of using recovered material and recovered material-derived fuel must use such fuel capability to the maximum extent practicable. The proposed regulatory residence and temperature requirements are based upon assuring that worst case wastes are destroyed efficiently. The dilemma provided by the conflicting goals of waste destruction and energy recovery may be resolved by having intermediate operating parameters for more easily destroyed wastes. The mechanism for doing this on a case-by-case basis is provided by Section 3004, which allows incinerators to operate under alternate combustion criteria provided an equivalent degree of combustion is demonstrated.

Power Plant and Industrial Fuel Use Act of 1978. The Power Plant Act, P.L. 95-620, penalizes new installations of boilers greater than 29.3 megawatts (100 x 10^6 Btu per hour) if they are not capable of burning coal. The penalty is in the form of a tax collected by the Internal Revenue Service on annual usage of gas and oil. The Act will provide an incentive for installing intermediate size coal-fired boilers.

The proliferation of coal-fired units will provide more sites with the option of cofiring their waste streams in a boiler. In North Carolina, 17 percent of the sites that had an industrial incinerator also had a boiler greater than 29.3 megawatts. Over 49 percent of the sites that had an industrial incinerator also had some type of boiler.

The Power Plant Act will promote a decrease in the segment of the industrial incinerator population used for volume reduction. These wastes can easily be prepared for energy recovery by shredding. Unlike municipal waste, the industrial volume reduction streams have a low moisture content.

State and Local Regulations. State and local regulations have generally tipped the economics of disposing of non-hazardous wastes in favor of land disposal. Units operated for volume reduction comprised 55 percent of the existing units installed prior to 1976. During the last 3 years, 42 percent of the new installations were for volume reduction, as shown in Figure 4-12. State regulations prohibiting open burning have provided an incentive for installing incinerators to be used for resource recovery. Formerly, insulated wire and paint hooks used to hold parts in a spray booth were frequently



[a] Sample consists of incinerators in Georgia, Illinois, Ohio and Texas with use and date data available.

Figure 4-12. Use trends in sample.

burned in the open at metal scrap yards, wire plants, and some of the establishments that paint parts. Figure 4-12 shows that 27 percent of the incinerators installed prior to 1976 in the existing population are used for resource recovery. One-third of the installations made during the last 3 years consist of units for resource recovery.

Recycling Incentives. Recycling incentives are reducing waste streams destined for volume and waste reduction incinerators and increasing the amounts of waste processed in resource recovery units. The National Energy Act provides incentives for recycling by allowing a 20 percent tax credit for purchases of equipment used to process materials for recycling. The credit applies to equipment placed in service on or after October 1, 1978, and covers nonferrous metals, paper, textiles, rubber, and other materials.[41]

Changing economic situations have made new and lower grades of materials candidates for recycling. For example, particleboard started as a low-grade substitute for plywood. Today, when the lumber and furniture industries are generating less wood waste, a seller's market exists for wood waste because of the multitude of uses for particleboard. The unique characteristics of this material have created some uses that cannot be met by plywood. The demand for wood waste as a raw material or energy source will continue to curtail incineration of wood waste.

Plastics are also being removed from industrial waste to some extent. Various secondary plastic processing operations include waste generation as an inherent part of the process. Markets for the materials for use in lower-grade plastic products such as flower pots and septic tank drain lines have taken some of these materials out of industrial waste streams.

Energy Incentives. The rising cost of both energy and waste disposal has resulted in a lowering in the cost breakpoint where energy recovery becomes an attractive alternative to incineration. Additional incentives are provided by tax credits for installing equipment that will prepare waste for energy recovery and tax penalties that will promote the installation of units capable of handling solid wastes.

It is estimated that 99 percent of the large waste combustion units and 75 percent of the small waste combustion units sold by major incinerator manufacturers will have heat recovery.[6] (The size ranges included in "large" and "small" were not elaborated.) All of these manufacturers offer units with heat recovery. Two alternatives offered by manufacturers for recovering heat are shown in Figures 4-13 and 4-14.[42-43] One installation of this type is a tube bundle heat exchanger mounted on an incinerator stack. In this case the hot flue gases flow on the inside of the tube bundle, and plant air passes on the outside of the tubes. The temperature of the resulting hot air is controlled by adjusting the air flow rate through the exchanger.[44] Such steam generators would be addressed through other NSPS regulations.

Investigations have shown that chlorine, as hydrochloric acid (HCl) and/or solid chloride deposits, contributes significantly to high- and low-temperature corrosion of structural materials in incinerators and waste-fired boilers.[6] This may slow the trend toward energy recovery from industrial waste. Some of these problems can be resolved by changes in boiler materials with regard to construction, waste segregation, or raw material switching. The total amount of chlorinated organic residues is estimated at 472,000 megagrams in 1978.[45] This is small relative to the approximately 17 million megagrams of combustible waste generated by industry.

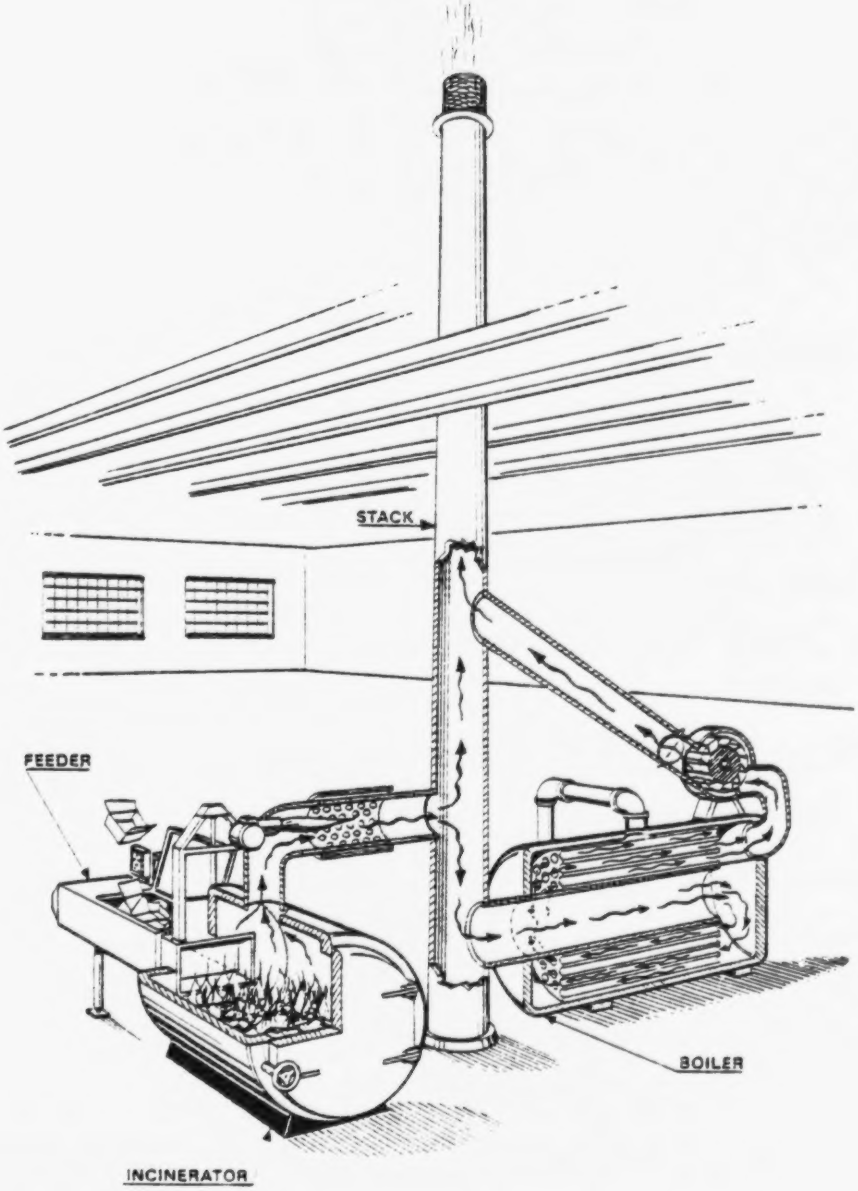

A-0204
STACK
FEEDER
BOILER
INCINERATOR

Figure 4-13. Flue gas-to-steam heat recovery.

A-0205

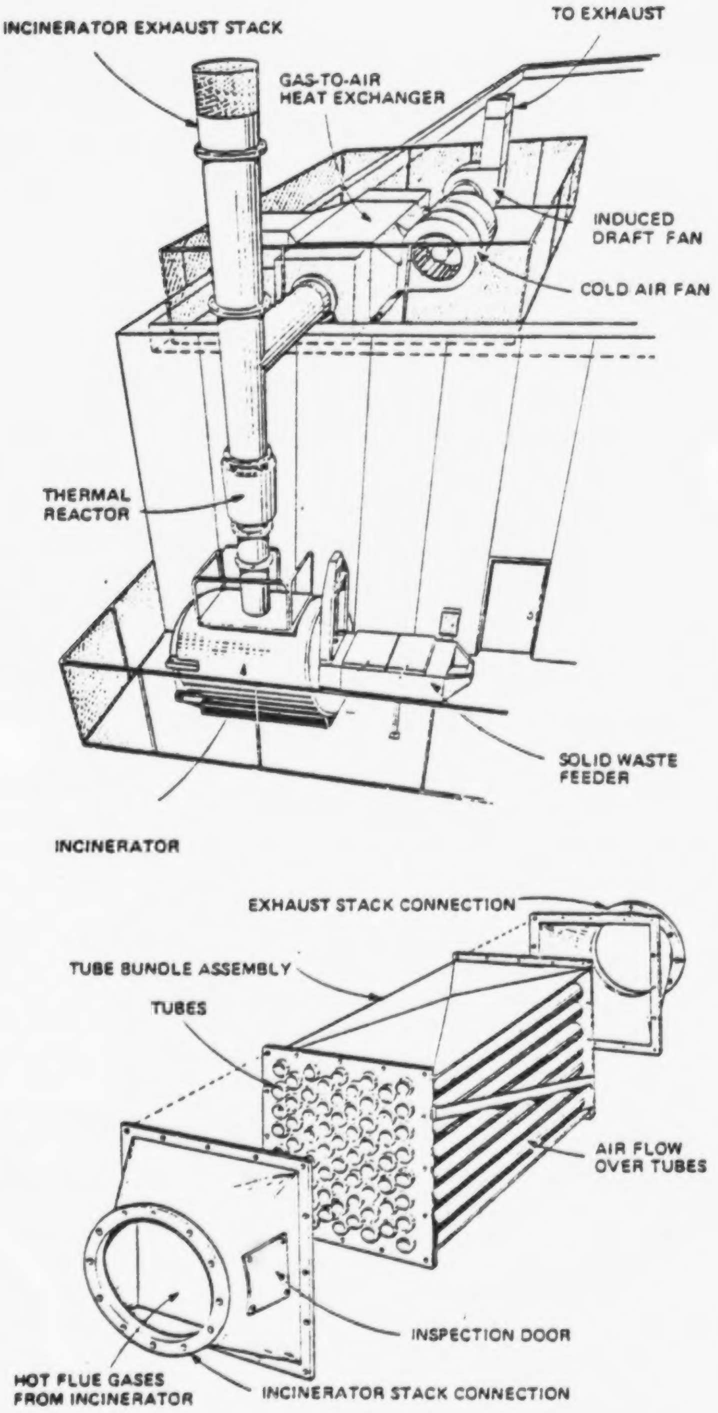

INCINERATOR EXHAUST STACK
TO EXHAUST
GAS-TO-AIR HEAT EXCHANGER
INDUCED DRAFT FAN
COLD AIR FAN
THERMAL REACTOR
SOLID WASTE FEEDER
INCINERATOR
EXHAUST STACK CONNECTION
TUBE BUNDLE ASSEMBLY
TUBES
AIR FLOW OVER TUBES
INSPECTION DOOR
HOT FLUE GASES FROM INCINERATOR
INCINERATOR STACK CONNECTION

Figure 4-14. In stack gas-to-air heat exchanger.

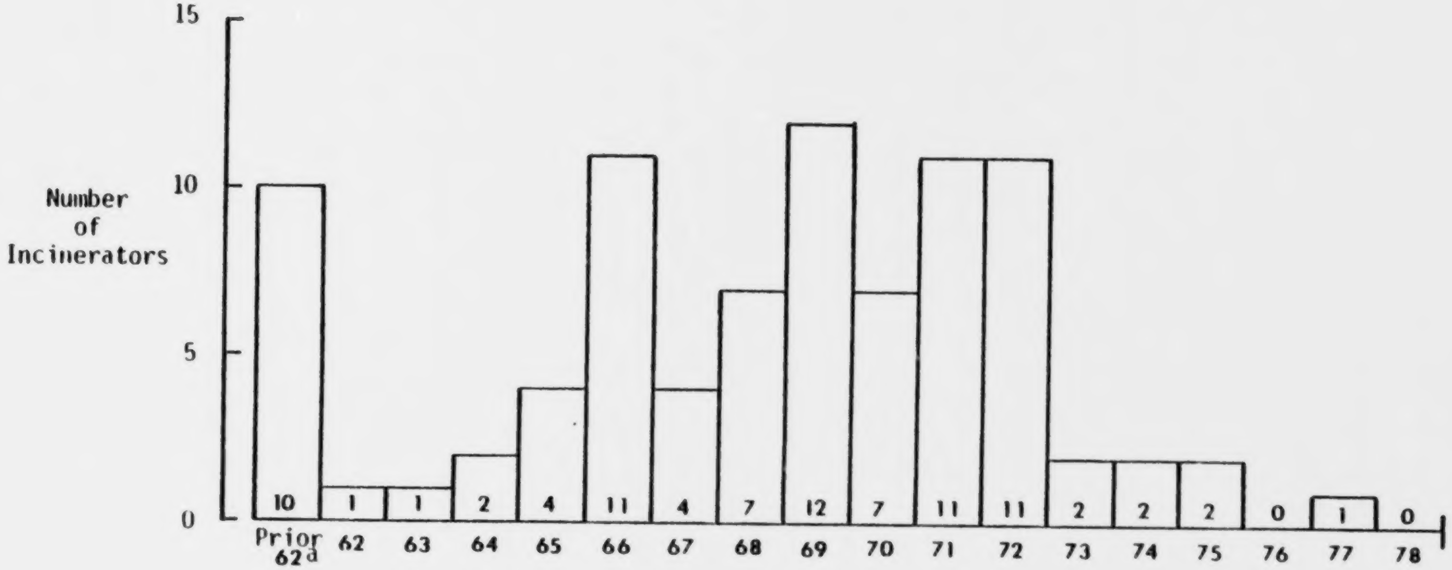
4.2.2 Future Growth

There are wide variations in the design, size, and uses of industrial incinerators. Correspondingly, the potential for growth is not the same for every segment of this heterogeneous population. The major factors that influence growth are government regulations, energy recovery, and resource recovery. The impact of each of these factors is dependent on the type of waste being burned. Therefore, segmentation by use and waste streams will be used as the framework for discussing growth trends.

A quantitative measure of growth trends in the industrial incinerator population cannot be derived directly from the data compiled from the six States in the sample because the number of incinerators with both adequate installation data and use data was minimal. Therefore, it will be necessary to determine growth trends by inference from other statistical breakdowns. These growth trends are presented in Figures 4-15 through 4-17.

None of the States sampled had comprehensive information on the age of the incinerators they had permitted. The only source of this type of information was the records of the City of Chicago Department of Environmental Control, presented in Figure 4-15.[46] These data are very current because Chicago requires annual permit renewal and licensing fees. Therefore, units that are shut down are promptly removed from the permitting systems. One incinerator in Chicago was 27 years old. The figure shows, however, that the number of units still in operation sharply dropped prior to the group installed in 1966. This implies a typical incinerator lifetime of approximately 13 years. The trend in new installations in the city is obvious: from an average of nine new units per year from 1966 to 1972 to only one new installation in the last 3 years. The average number of new

A-0206



[a]The four oldest units in this group were installed in 1951, 1954, 1956, and 1957.

Figure 4-15. Age of the existing industrial incinerator population in the City of Chicago.

A-0207

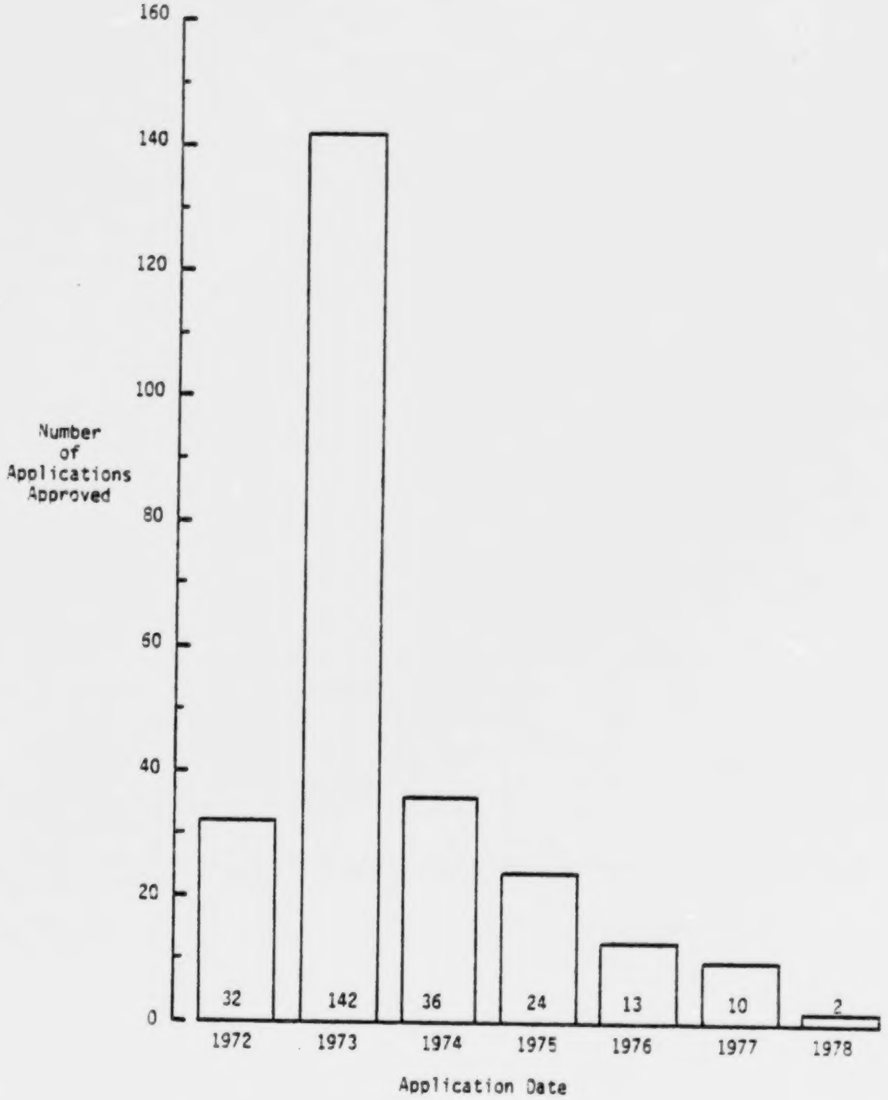


Figure 4-16. Applications for permits to operate an industrial incinerator in the State of Illinois.

A-0208

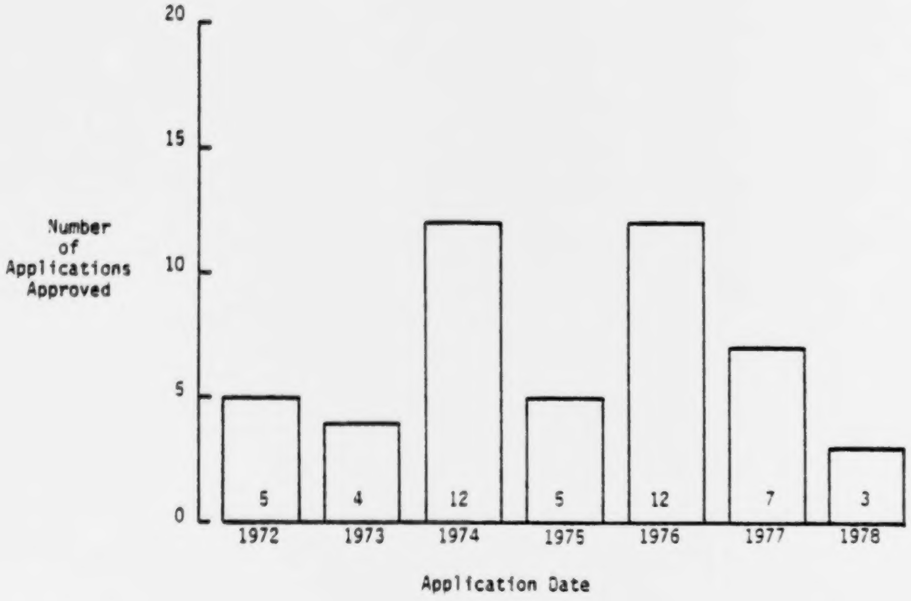


Figure 4-17. Applications for permits to operate an industrial incinerator in the State of Texas.

units installed from 1966 to 1972 could be even higher because units that were installed during this period and since taken out of service are not included.

In the absence of installation date information from the States, the date operating permits were requested has been compiled. This information was available in Illinois and Texas. Illinois did not begin requiring permits until 1971 when requirements were placed on both new and existing sources. The number of permit applications in the earlier years is an agglomeration of both new and existing sources and tells very little about new installations. The trend in the last five years, however, is obvious and a good representation of new installation trends. In 1974, 36 new units were installed. The number of new units dropped every year thereafter until it reached a low of two new installations for the entire State of Illinois in 1978. This information is presented in Figure 4-16. Permit applications that were denied are not included in the data.

The State of Texas does not require operating permits for existing sources. The requests for incinerator operating permits are shown in Figure 4-17. The trend in Texas is not as obvious as the others, although there is a consistent decrease in new installations each year from 1976 to 1978. Two hypotheses are given for the inconclusiveness of the Texas data. First, Texas has a sliding scale for determining allowable particulate emissions. This scale results in a more lenient emission standard than in Illinois and Chicago for units in the industrial size range. Second, Texas and its large chemical industry have a greater need for toxicity reduction units, which, according to Figure 4-12, are responsible for a growing share of new installations.

The Illinois data will be used to represent the national trend in incinerator population changes for two reasons. First, of the six States sampled, Illinois was the only one that had the needed information and a large enough incinerator population to determine trends. Second, the Illinois data are supported by qualitative statements on new installations made by officials in the Office of Solid Waste Management and several State agencies.[47,48,6,49]

The Illinois data consisted of 259 units, with two installations in 1978. Thus, new installations in 1978 equalled 0.8 percent of the existing population. In projecting growth trends, an optimistic 1 percent of existing population will be used for the annual number of new installations each year. Based on the 13-year lifetime derived from the Chicago data, 8 percent of the existing 1978 population will be used as the number of units that go out of service each year.

Volume Reduction. New installations of incinerators used for volume reduction are expected to follow the general trends for incinerators. This means that the population would experience an 8 percent loss annually due to units taken out of service and only a 1 percent gain in new installations, or approximately an annual decrease of 7 percent between 1980 and 1985. Several factors could increase the downward trend in volume reduction units:

- Incentives for resource recovery removing wood, paper, and plastics from these waste streams. Tax credits for resource recovery equipment compound the effect of these incentives.
- Higher energy costs, which provide incentives to use the materials in waste-fired boilers, and the increased availability of boilers capable of cofiring wastes.

- Discouragement of replacement or modification in States with more stringent emission regulations for new sources.
- Increased demand from the growing refuse-derived fuel (RDF) business for these waste streams.

One factor that could possibly reverse this trend is RCRA's requirement that all open dumps be replaced with sanitary landfills, which will raise the cost of landfilling. However, no evidence was found to indicate that in areas where States had implemented RCRA-type requirements there was an increased activity in incinerator installations. Landfilling is expected to remain more cost-effective than incineration.

Toxicity Reduction. New installations of incinerators for the purpose of toxicity reduction are expected to follow the general trend for incineration. Growth projections for this segment of the population assume that existing units will go out of service at a rate of 8 percent per year, and new installations each year will equal 1 percent of the population in the previous year. This will result in roughly a 7 percent annual decrease in total population from 1980 through 1985. The following factors support these assumptions or provide an incentive for a more rapidly declining population:

- Resource recovery efforts, including solvent recycling firms and industrial waste exchanges, which reduce the amount of these waste streams.
- Higher energy costs, which provide incentives to use the materials in waste-fired boilers, and the increased availability of boilers capable of cofiring wastes.

- Discouraging of replacement or modification in States with more stringent emission regulations for new sources.

Factors that may provide incentives for an increase in the population include the following:

- The possiblity that RCRA may discourage the combustion of hazardous substances in waste-fired boilers.
- The possibility that incineration could be less expensive than landfilling if the hazardous waste landfill regulations are adopted and the incineration regulations are not.

Resource Recovery. New installations of incinerators for the purpose of resource recovery are expected to follow the general trend for incineration. Initially, because of the various incentives for recycling discussed earlier, this major use category of incinerators was expected to exhibit considerable new installation activity. Due to these expectations and the potential for a high NSPS benefit, this use grouping was analyzed in more depth than the other two use groupings. From the analysis, however, it was concluded that the trend is away from resource recovery incinerators, primarily because of the high cost of operating an afterburner for emission control and the availability of alternative recycling processes. The only exception to this trend is in the subcategory of motor incinerators. New motor incinerators will be installed at an estimated rate of 100 units per year between 1980 and 1985.

The population of resource recovery incinerators is broken down for analysis, by the materials they process, into the following major subcategories: copper wire, electric motors, x-ray film, brake shoes, and steel drums. Changes in each subcategory are influenced by a unique set of costs, market incentives, and process alternatives. Therefore, each subcategory is discussed individually.

- Wire Incineration. Contacts have been made with groups knowledgeable about the demand side of the wire incinerator market, including owners, trade associations, and State agencies. These contacts revealed that incineration is no longer the preferred method for recovering copper from scrap wire. It can also be inferred from changes in the supply segment of the marketplace that the manufacturers of incinerators have responded to a small demand for the units by owners and operators.

Many factors are discouraging the use of incineration. Most of them are directly related to the costs of obtaining usable metal from the scrap. Despite increasing prices for copper, the net profit margin on a pound of copper for the owner of an incinerator has declined steadily for the last 14 years.[50,51] As a result, owners of recovery facilities now prefer two mechanical processes--wire chopping and stripping. Chopping is the total granulation of the insulated wire followed by air classification. Stripping is the forcing of insulated wire through a set of gears and rollers that remove the insulation. Stripping is applicable to only large diameter wires. It can be accomplished at a cost of 2.8 to 6.1 cents per pound of copper, depending on the diameter. Chopping is sufficient for most types and sizes of wire. Material can be processed at a cost of 6.3 to 9 cents per pound of copper, depending upon equipment utilization.[52] In some cases, the processing cost of stripping and chopping is not significantly lower than incineration. However, these mechanical processes result in a much cleaner copper product which commands a 10 cents per pound premium over the output of an incinerator.[53] Some owners of these units are also able to obtain additional revenue by selling the insulation.

The plastic insulation is easier to market than the plastic backing of x-ray film, to be discussed in a later section, because the insulation is generally made from polyethylene, polypropylene, or polyvinyl chloride (PVC). These three plastics have a variety of uses that do not require close product or processing tolerances such as flower pots, septic tank drain pipes, and shoe soles. The plastic material that comprises the x-ray backing is polyester, which is generally used in products or processes that demand close tolerances, such as gears and films, and which tend to limit the applicability of recycled materials.

In conjunction with the availability of less costly processes, the following factors discourage new wire incinerator installations:

- The cost of fuel is increasing. Incineration is an energy intensive process. Fuel for the afterburner, and in some cases the primary chamber, has a significant impact on total operating cost.
- The use of PVC as a wire insulation is more prevalent.[54] PVC is difficult to burn, requiring additional heat input to the primary chamber. Emissions from burning this type of insulation include chlorine, acid gases, phthalic anhydrides, and phosgene, all of which necessitate a scrubber.[55,56] The need for more sophisticated equipment requires an initial investment of $90,000 versus $30,000 for a unit which is not designed for PVC. The resulting processing cost is about 12 cents per pound of copper.
- Aluminum is replacing copper in many wire applications.[57] The aluminum wire precludes the use of incineration because of the low melting point of the metal.[58] Owners of incinerators who now

handle aluminum wire from utility companies expect their incineration operations to decrease in the future.

- All the common insulations are derived from oil. Therefore, their cost has followed the price of petroleum. Some processors have been able to find markets and additional revenue from plastic waste.[59] When incineration is used, all the plastic is destroyed.

The typical copper wire incinerator processes 1,000 pounds of insulated wire per hour.[20] The units range in capacity from 500 to 3,000 pounds per hour. No new large installations are foreseen in the near future. For small units, a very limited number--fewer than 10 per year in 1980 declining to no new installations by 1985--is projected. The Wire Association International concurs with this assessment.[60] One-third of the owners of incinerators contacted (owners who have permits from the State) indicated that their units were no longer in use.[54,61,62,63] None of the owners who still used their units intended to replace them because they expected the unit to last indefinitely if they periodically replaced the refractory, which costs only one-third as much as a total new unit.[64,65]

Some insulated wires are difficult to process mechanically because they contain a jelly-like filling, a wax coating, or an insulating material that will not separate from the metal after the wire has been processed. These types of wire do not comprise a major fraction of the total amount of wire recycled each year. Incineration will continue to be used to process them; however, no new units are expected to be installed specifically to recover these materials. As incineration costs continue to rise, the wires that cannot be mechanically processed either will no longer be recycled or will be shipped out of the country for processing. These materials are already exported on a large scale to places where they can be either burned without pollution controls or manually disassembled by low-paid foreign labor.[66]

- Motor Incineration. Motor incinerators are used to remove varnish, epoxy, or a thermoplastic coating from the windings of electric motors. Contacts with owners and manufacturers of motor incinerators have indicated continued growth in new installations of these types of units. However, these units are typically very small and are very rarely operated at capacity.

Some competing processes for handling the motors involve chemical stripping. These processes involve the use of hazardous materials. The trend seems to be away from the chemical method and toward incineration.

New installations are estimated at 100 units per year. This figure is based on the sale of new units reported by one manufacturer. Other manufacturers of these units have not been located. Every owner we contacted owned a unit manufactured by this company; therefore, it appears to dominate the market and is perhaps the sole source of the units. The owners contacted expected their units to last 12-25 years.[67,68] Half the owners expected to purchase a replacement unit eventually, and the remainder expected to replace the refractory periodically but to use the same unit indefinitely.

Some motors that are to be discarded rather than repaired are incinerated at scrap yards. Based on only one contact, these motors are believed to be processed in a wire incinerator.[62]

- X-ray Film Incineration. A more detailed look at x-ray film incineration has indicated that there will not be any new installations of this type. Any units that are built will have heat recovery and, therefore, will fall within the realm of the waste-fired boiler standard.

The high price of silver has provided an impetus for recovering the precious metal from scrap materials. Medical and industrial x-ray material are two high-grade sources. Photographic and lithographic papers are two low-grade sources. Both grades of sources have historically been recovered by incineration. The trend for high-grade waste is away from incineration and toward wet processing.[69,70,71,72,73] There are currently two wet silver recovery processes. One is based on caustic and the other relies on enzymes to break up the organic emulsion that contains the silver halides.

The wet system offers the processor several advantages. Typically, incineration results in a loss of 15-25 percent of the silver through the stack because of vaporized metal halides. A wet system precludes losses of this type. Incineration destroys the plastic film base. The wet process yields a clean plastic film that is potentially marketable. Based on the current price of virgin polyester resin, the plastic recovered may be worth more than the silver recovered per pound of x-ray film. No one contacted was able to report any current uses for the recovered plastic, but contacts indicated that there is great interest.[22] However, in the near term, the plastic may be landfilled.

The low-grade materials will continue to be recovered by incineration because no alternatives exist. The wet process is not applicable. These scrap materials are not sold as are the higher quality sources, but are frequently given away. The low quantities of silver obtained usually do not justify significant capital investments. The material may, therefore, be open burned or processed in an existing incinerator. It is not likely that a new incinerator would be purchased unless it is used to provide energy for the site.

No new installations are expected. One manufacturer of a wet system stated that he now has orders from seven owners of incinerators who want to switch to his wet process.[71] These orders alone would result in a 7 percent decrease in the incinerator population.

The conclusion that there will not be any new installations is supported by the small number of equipment suppliers. Only two are known. One has sold seven units in the last four years.[74] The second has 40 units in the field and expects to sell three to five units per year over the next 4 years.[70] The latter firm's sales estimate is believed to be overly optimistic and is not reflected in the new installation forecast.

- Steel Drum Incineration. Most drum incinerators are either custom made or home built. They range from batch units that process one drum at a time to units that continuously process 700 drums per hour. Based on an EPA/Industrial Environmental Research Laboratory (IERL)-Cincinnati study, the average drum incinerator processes 125 drums per hour.[75] The steel drum incinerator population will remain constant with very little new installation activity. The total population size is very small, and expansion is being stifled by high energy cost and alternative processing methods.

Used drums can be reclaimed by either cleaning with a hot caustic solution or incineration. The caustic process is the preferred method because it is cheaper. Incineration is generally reserved for drums with a residue that cannot be dissolved by the caustic process.

Drum incineration is expensive because of the high cost of operating the afterburner which is essentially for compliance with State regulations. Even with the afterburner, occasional smoke violations occur. The National Barrel and Drum Association has undertaken a study to prove to the Ohio EPA that occasional smoke violation is unavoidable because of the nature of drum reclamation.[76] The results of the study will not be out until July or August 1979. Since afterburners are used on all the resource recovery incinerators located during this study, the impact of the auxiliary fuel cost seems to be more significant when the product is steel drums than when it is copper or silver.

The national population is estimated at 39 units according to the IERL study released in April 1978.[24] No new installations are projected, and a decline in the number of units is expected. Owners of one drum incinerator report that they have not used the unit in 1½ years because it is too expensive, and they only process drums that can be washed with the caustic method.[77] All the owners with units in operation who were contacted planned to replace the refractory periodically and use the same unit indefinitely.[78,79] One owner had a 20-year-old unit and could not foresee replacing it. One drum incinerator manufacturer stated that a large market never existed for the units, and their use was discouraged by pollution regulations and fuel shortages.[80]

- Brake Shoe Incineration. The use of incineration to recover the metal structure that supports the brake pad is on the decline as a result of change in the type of brakes being used. In addition to the bonded drum type, riveted drum and disc brakes comprise the major categories of brakes. Incineration can be used to recover only the metal shoe from the bonded drum type.

The following factors have reduced the need for brake incinerators:

- Historically, 80 percent of the drum brakes have been bonded. Now only 50 percent are bonded; the rest are riveted.[81]

- Drum brakes are no longer standard equipment on the front wheels of many new cars.

Because of the decline in demand for bonded brakes, no noticeable numbers of new units are projected for this population.

Off-site Incineration. Growth in the off-site reduction of hazardous wastes by incineration at centralized facilities is not expected to increase to the point where new facilities will be constructed.[30] A predominant problem in establishing a new facility is that community opposition to the facilities is mounting and in some cases is threatening their operation. In Bridgeport, NJ, residents are seeking to restrict or shut down a 25-acre treatment facility owned by Rollins Environmental Services, Inc. Opposition to existing facilities has been reported around the nation.[30] RCRA's incinerator requirements may also lessen the economic attractiveness of incineration. However, since these firms generally utilize larger incinerators, the additional control requirements will probably have less economic impact on these units than on their on-site counterparts. In addition, the manifest system requirements of Section 3002 of RCRA further complicate the procedure and raise the cost of this waste reduction method. Cement kilns which have shown great promise as a waste disposal means appear to be a more likely growth scenario than expansion of existing off-site facilities. Therefore, no growth is projected for the centralized waste reduction segment of the industrial incinerator population.

Conical Incinerators. Data on wood-fired conicals were not compiled. A recent study of these units has estimated population through 1978.[82] These estimates have been extrapolated to 1980 and 1985. The estimates in Table 4-13 generally agree with opinions of State enforcement officials

Table 4-13. ESTIMATES OF NATIONWIDE POPULATION AND AIR CONTAMINANT EMISSIONS FROM CONICAL INCINERATORS

	Emission rate,[a] 1000 ton/yr					
	Year					
	1968	1973	1978	1980	1983	1985
Number of conicals	3330	835	490	360	163	30
Particulates	374	65	14	10	5	0.9
Carbon monoxide	1400	255	69	51	23	4
Hydrocarbons	105	17	1.7	1.3	0.6	0.1
Polynuclear hydrocarbons	0.116	0.020	0.0044	0.0032	0.0015	0.0003

[a] Based on an average burning rate of 3.5 units/hr and an operating schedule of 16 hrs/day, 5 days/week, 50 weeks/yr. One unit of wood wastes, containing around 50 percent moisture, weighs 2,000 lbs (1 ton). Estimated emissions from 1968 to 1978 assumed improving control technologies. Level of control was assumed to be constant from 1978 to 1985.

regarding the trends in conical population. In view of demands for wood waste as a raw material and energy source, the population is probably overestimated.

4.3 SUMMARY OF POPULATION AND GROWTH TRENDS

The 1980 population of industrial incinerators is estimated to be 4200 units, and it is expected to decline to 3700 units by 1985. The use distributions of the present and future populations are presented in Table 4-14. The general trend is away from incineration in most use categories because of the availability of economically attractive alternatives. Competing processes include land disposal techniques and those that allow either materials or energy to be recovered. The only exceptions to the general trend in reduced incinerator demand are two types of resource recovery units. They are copper wire and electric motor incinerators.

Even though the total population of incinerators in use for volume and toxicity reduction is declining, some new installation activity is expected. Over the next 5 years, 63 new volume reduction and 32 new toxicity reduction units are forecasted. In the resource recovery group no noticeable new installation activity is foreseen for units handling steel drum, x-ray, and brake shoe waste streams. Between 1980 and 1985 new installations of copper wire and electric motor incinerators are expected to number 25 and 500, respectively. The emissions and the potential benefit from an NSPS are discussed in the next section.

Table 4-14. FIVE-YEAR PROJECTED INDUSTRIAL INCINERATOR POPULATION

Population segment	Year	
	1980	1985
Volume reduction (other than conical wood)	1500	990
Toxicity reduction	640	420
Resource recovery	1700	2200
Off-site	10	10
Conical (wood)	360	30
Total	4200[a]	3700[a]

[a] This value does not equal the sum of its components because it is rounded to two significant figures.

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5. SOURCE TESTING AND EMISSION ESTIMATES

This section discusses readily available source test data collected during this study. The data are classified by waste streams and summarized in tables that enable some comparison to be made between the controlled and uncontrolled emission levels found in the data and those given in Compilation of Air Pollutant Emission Factors (AP-42). The emission collection and analysis procedures used on incinerators are described. Finally, the nationwide emissions of all the criteria pollutants are estimated for the year 1978 and 1983.

5.1 SOURCE TEST DATA

This section presents a compilation of the readily available emission data on the principal pollutants expected to be found in the flue gas of an industrial incinerator. Data on nonindustrial units were also compiled for use in case the control technology is determined to be transferable to the industrial sources. Test data on both criteria air pollutants and other air pollutants were assembled.

Whenever possible, the various types of units used to report measured emissions were converted to common units, usually the same units as those of the AP-42 emission factor. However, the information necessary to make this conversion was often not available in test records, and time constraints did not allow contacts with personnel involved in field tests in order to obtain the necessary information. Because particulates were expected to be the primary pollutant of concern, their emission data are dealt with more thoroughly than those of the gaseous pollutants. Most of the particulate data collected were converted to g/kg (lb/ton) of feed using the conversion factors in Table 3-3 (Chapter 3). Using these factors required that some assumptions which are discussed fully in Section 3 be made.

As the tables indicate, the data often show higher emission levels for controlled sources than for uncontrolled sources. This incongruity is usually due to the fact that tests on uncontrolled and controlled sources were conducted on different sources.

5.1.1 Sources of Data

Sources of incinerator emission data were identified through an extensive literature search of EPA documents, test reports published by State air pollution control agencies, and manufacturers' specifications. In addition, EPA regional offices, State air pollution control agencies, and local air pollution control district (APCD) offices were contacted by telephone. Additional telephone contacts were made with universities and private companies involved in studies on waste disposal and incineration.

Most of the emission data summarized in this section were obtained from State air protection agencies and local enforcement offices (APCD's). The other data were obtained from EPA offices and published field test reports. Data were collected on a total of 513 emission tests performed on 159 sources.

Data were most readily available for the pathological, general industrial refuse, and trash incinerators. Particulate matter (PM) was the pollutant most often tested. Generally, PM is the pollutant of concern when the unit's compliance with a State's air regulations is in question. Therefore, PM emissions are often tested to ensure compliance with local environmental standards. Emission test data on NO_x, CO, HC, SO_2, and Cl_2 reported in this study are limited. Data have been requested from additional sources, but have not yet been received. A general summary of the data collected is presented in Table 5-1.

A rigorous breakdown of the data by incinerator design was not possible, since no standard definition exists which differentiates among various incinerator designs, and because the incinerator descriptions in the test records were incomplete. Because the most readily available and explicit test parameter was the waste processed, the test results were grouped by incinerator use or waste. All the data compiled were compared to AP-42 emission factors. For some wastes, AP-42 listed a different emission factor for each design type. Because the emission data were categorized by waste type and not by design, several emission factors were found to apply to a given category. When this situation occurred, the data were presented as a range in the summary tables.

5.1.2 Municipal Refuse Incinerators

Table 5-2 summarizes emission test data from municipal refuse incinerators. Source test information was acquired primarily from reports for 13 incinerators by Environmental Engineering, Inc. and the GCA Technology Division. The largest incinerators in the group are located in New York City. They consist of a bank of four furnaces with a total capacity of 1000 tons of refuse per 24 hours. Combustion air is supplied at a number of locations, and unburned hydrocarbons are combusted in a secondary chamber. Then a combination of water sprays, multi-clones, venturi scrubbers, and mist eliminators treat the flue gases, primarily for PM removal.

Table 5-1. COMPILED TEST DATA FROM INCINERATORS

Waste burned	No. of sources	No. of tests	Pollutants sampled	Range in incinerator waste feed capacity kg/sec (10^3 lb/hr)	References
Municipal	13	42	PM, SO_2, NO_x, HC, HCl, CO	0.32 - 20.8 (2.5 - 165)	5-1, 5-2, 5-3, 5-4, 5-5, 5-6, 5-7, 5-8, 5-9
Pathological	37	137	PM, CO, NO_x, HC	0.01 - 0.37 (.050 - 2.9)	5-1, 5-8, 5-9, 5-10, 5-11
Municipal and industrial sludge	21	71	PM, SO_2, NO_x, CO, HCl, Hg, Carbonyls aldehydes	0.06 - 1.26 (0.5 - 10.0 dry sludge)	5-1, 5-2, 5-3, 5-4, 5-5 5-6, 5-7, 5-8
Industrial process waste[a]	23	82	PM, SO_2, NO_x, CO, Cl, HC	.009 - 0.51 (0.07 - 4.0)	5-1, 5-8, 5-9, 5-11, 5-12, 5-13, 5-15
Trash and rubbish	64	171	PM, NO_x, SO_2, CO	0.01 - 0.63 (0.1 - 5.0)	5-1, 5-9, 5-12, 5-16, 5-17
Agricultural (gin waste)	1	10	PM	0.32 (2.5)	5-12

[a] Industrial process waste includes waste oil and liquid waste, paint racks, film, wood, wire, electrical products, and explosive products.

Table 5-2. SUMMARY OF EMISSION TEST DATA FROM MUNICIPAL INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]		AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean] kg/Mg (lb/ton)	References
		kg/Mg (lb/ton) feed	ppm			
Particulates	13	0.2 - 19.5 [5.8] (0.3 - 38.1 [11.6])	-	7.5 - 15.0 (15.0 - 30.0)	0.37 - 0.91 [0.48] (0.73 - 1.82 [0.97])	5-1, 5-3, 5-4, 5-5, 5-6, 5-7, 5-8, 5-9, 5-18
NO_x	3	-	48	1.0 (2.0)		5-5, 5-7
SO_2	2	10.7 - 16.0 [13.0] (21.32 - 32.0 [26.0])	316-438 [372]	1.3 (2.5)	4 ppm[a]	5-2, 5-7
HC	1	-	30	0.8 - 7.5 (1.5 - 15.0)		5-5
HCl	3	1.0 - 3.5 [2.7] (2.0 - 7.0 [5.35])	98	-		5-2, 5-5
CO	1	-	6 - 33 [19]	10.0 - 17.5 (20.0 - 35.0)		5-5

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[a] Sulfur content of fuel or waste was not given so it is not known if this is a result of the controls of low sulfur feed.

Uncontrolled PM emissions for the municipal data compiled were generally lower than the AP-42 emission factor, although the emissions varied both above and below the factor. The mean controlled PM emissions were approximately one-tenth of the uncontrolled level. Nitrogen oxide (NO_x), sulfur oxide (SO_x), hydrocarbon (HC), hydrochloric acid (HCl), and carbon monoxide (CO) emissions were also tested. Only a few tests were available on NO_x emissions, which averaged 48 ppm and could not be compared to AP-42 factors because of different units of measurement. Average SO_x emissions were roughly 10 times the AP-42 factor. However, this situation cannot be considered representative because of two factors. First, only two test reports were used to obtain the SO_x data. Second, both units were burning an unspecified amount of residual oil together with the municipal waste. Emissions of HC, HCl, and CO were tabulated, but, again, because of different units of measurement, these cannot be compared with AP-42 factors.

5.1.3 Pathological Waste Incinerators

Incinerators that burn hospital waste, or Type 4 wastes, were grouped together as pathological units. Usually these wastes consisted of bandages, dressings, and animal remains. Occasionally other wastes were burned. The majority of the emission data were obtained from the Illinois EPA. Additional sources included the Indiana State Board of Health, State of Georgia, City of Chicago, State of California, and the Fresno, California Air Pollution Control District. These sources provided a significant amount of particulate emissions data, but only a limited amount of information on CO, NO_x, and HC.

The emissions data collected on pathological incinerators are summarized in Table 5-3. A total of 85 test runs were compiled, of which 89 percent

Table 5-3. SUMMARY OF EMISSION TEST DATA FROM PATHOLOGICAL INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]	AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]	References
Particulates	37	0.52 - 16.3 kg/Mg [3.11] (1.04 - 32.6 lb/ton [6.23])	4.0 (8.0)	0.05 - 17.1 kg/Mg [2.98] (0.1 - 34.2 lb/ton [5.97])	5-1, 5-8, 5-10, 5-11
NO_x	2	141.2 - 222.1 g/m³ [132.4] (18.0 - 97.0 gr/scf [57.8])	1.5 (3.0)	-	5-1, 5-9, 5-10
HC	11	0 - 397 ppm [87.8]	0.0	0 - 397 ppm [19.7]	5-10
CO	20	0 - 341 ppm [190.3]	0.0	0 - 60 ppm [17.6]	5-10

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were tests on units with control equipment, including 10 units with scrubbers and possibly afterburners and 28 with only afterburners. The particulate emissions from units controlled with scrubbers ranged from 0.035 to 4.22 g/kg (0.07 to 8.44 lb/ton), with a mean of 1.74 g/kg (3.48 lb/ton). Two of the scrubber tests reported particulate removal efficiencies of 75 percent and 84 percent. The units controlled with only afterburners had particulate emissions ranging from 0.05 to 17.1 g/kg (0.10 to 34.2 lb/ton), with a mean of 3.43 g/kg (6.86 lb/ton). The uncontrolled particulate emissions ranged from 0.52 to 16.3 g/kg (1.04 to 32.6 lb/ton), with a mean of 3.11 g/kg (6.23 lb/ton). The upper emissions level for incinerators controlled with only an afterburner is close to the upper emissions level for uncontrolled units, which could indicate that the dependability of afterburners as a control device is questionable.

5.1.4 Emissions from Sludge Incinerators

Emissions data were obtained for three general classes of sludge incinerators:

- Multiple-hearth, fired with sewage sludge
- Fluidized-bed, fired with sewage sludge
- Other designs, fired with either sewage or industrial sludge

The major sources of emissions data were the San Francisco Bay Area Air Quality Management District (BAAQMD) and the State Air Control Agencies of Indiana, Illinois, and Georgia. Data from 44 tests made on 24 sludge-burning incinerators are summarized in Table 5-4. The data indicated that emission control equipment for sludge incinerators usually included venturi or wet cyclonic scrubbers.

Table 5-4 SUMMARY OF EMISSION TEST DATA FROM SLUDGE INCINERATORS, SI UNITS (ENGLISH UNITS)

Design type/ waste fuel	Pollutant	No. of sources tested (no. of tests)	Uncontrolled emissions kg/Mg (lb/ton)[a] feed	AP-42 emission factor kg/Mg (lb/ton) burned	Controlled emissions [mean] kg/Mg (lb/ton)	References
Multiple-hearth burning sewage sludge	Particulates	5 (9)	no data	50.0 (100.0)	0.14 - 2.0 [0.84] (0.28 - 4.0 [1.68])	5-1, 5-3, 5-5
	CO	5 (6)	no data	0	0	5-1, 5-4
	NO_x	6 (12)	no data	2.5 (5.0)	11.5 - 271.6 ppm [77.1]	5-2, 5-4
	SO_2	7 (14)	no data	0.5[b] (1.0)	2.0 - 14.3 ppm [5.3]	5-1, 5-2, 5-4
	Hg	1 (3)	no data	-	0.00012 - 0.0030 [0.00114] (0.00024 - 0.0060 [0.00228])	5-3
Fluidized-bed burning sewage sludge	Particulates	4 (12)	no data	50.0 (100.0)	0.35 - 2.8 [1.3] (0.70 - 5.6 [2.6])	5-1, 5-2, 5-4
	SO_2	4 (7)	no data	0.5 (1.0)	0 - 200 ppm [64.6]	5-1, 5-2, 5-4
	NO_x	4 (9)	no data	2.5 (5.0)	0 - 173 ppm [76]	5-1, 5-2, 5-4
Other incinerator designs burning sewage or industrial sludge	Particulates	3 (20)	1.3 - 7.3 (2.6 - 14.6)	50.0 (100.0)	0.09 - 3.3 [0.86] (0.18 - 6.6 [1.72])	5-1, 5-6, 5-7, 5-8
	SO_2	1 (2)	no data	0.5 (1.0)	16 - 43 [29]	5-1
	NMHC	1 (3)	no data	-	0 - 9.5 ppm [3.2]	5-1

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[a] kg/Mg (lb/ton) refers to kilograms (pounds) of pollutant emitted per Mg (ton) of dry sludge charged.

[b] Total SO_x.

The most detailed information available was on multiple-hearth incinerators, which accounted for nearly two-thirds of all sludge incinerator test data found. Twenty-eight tests and 12 sources contributed to the data for fluidized-bed incinerators burning sewage sludge. Although the ranges were nearly identical, particulate emissions per ton of dry sludge charged averaged 56 percent higher than multiple-hearth design emissions. Though sufficient test data were available to standardize particulate emissions to the units of grams/kilograms (lb/ton), in most cases SO_x and NO_x emissions were available only in terms of concentration. The other types of sludge incinerators include all those of unspecified design and one with vortex-corner suspended firing. A total of 24 tests were made on four sources burning both sewage and industrial sludges. Controlled particulate emissions for this category averaged slightly higher than for the multiple-hearth category but less than for the fluidized-bed design. The average controlled SO_2 emissions for this third category fell between the other two categories. Emissions of non-methane hydrocarbons were generally low, less than 10 ppm. Some emission control systems consisted of wet scrubbers as the primary particulate control equipment used in combination with a cyclone. In all cases, some control equipment was used. Nearly half the sludge incinerator test reports contained auxiliary fuel data. Sixty-one percent indicated that gas was used as the fuel; 39 percent indicated distillate oil as the fuel.

AP-42 lists only one category of sludge incinerators and does not give factors for different design types. Therefore, the AP-42 factor is listed as the same for each design category.

5.1.5 Trash Incinerators

Trash incinerators burn a variety of wastes ranging from 100 percent cardboard to widely mixed refuse, including rubber, plastics, animal fats, foodstuffs, and wood wastes (pallets). Many data sources did not adequately define the composition of the wastes they incinerated, but instead used only general terms such as "refuse," "garbage," or "mixed solid wastes." The emission data collected and compiled are summarized in Table 5-5. The Illinois EPA was a major information source; Oregon, Indiana, Georgia, and Chicago contributed significant amounts of additional emission data. Other sources of information were the EPA Source Test Data System (SOTDAT) and the Fresno APCD.

The majority of the controls were afterburners (some with cyclones), venturi scrubbers, and wet impingement scrubbers. Particulate emissions ranged from 0.008 to 0.487 gr/dscf, which is equivalent to 0.07 to 4.1 g/kg (0.133 to 8.10 lb/ton). This equivalency assumes a waste of 50 percent water and 50 percent cellulose. The emissions of the gaseous pollutants were reported in parts per million and therefore could not be compared to AP-42.

5.1.6 Agricultural Waste Incinerators

Test reports were found for only two agricultural waste incinerators, and both of those burned only cotton gin waste. The data, which are summarized in Table 5-6, were obtained from the California Air Resources Board and EPA's Source Test Data System (SOTDAT). One incinerator was equipped with a cyclone; the other source used no flue gas controls. The mean level of particulate emissions from the controlled unit exceeded the mean level of the emissions from the uncontrolled unit. This incongruity was due

Table 5-5. SUMMARY OF EMISSION TEST DATA FROM TRASH INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]	AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]	References
Particulates	64	0.06 - 4.05 kg/Mg [0.67] (0.13 - 8.11 lb/ton [1.35])	3.5 - 7.5 (7.0 - 15.0)	0.35 - 1.0 kg/Mg [0.62] (0.7 - 2.0 lb/ton [1.24])	5-1, 5-9, 5-12, 5-16 5-17, 5-18
SO_2	1	-	1.25 (2.0 - 5.0)	5.1 - 10.6 ppm [7.9]	5-17
NO_x	1	-	1.0 - 1.5 (2.0 - 3.0)	9.6 - 14.9 ppm [12.3]	5-17
CO	31	0 - 500 ppm [104]	5.0 - 10.0 (10.0 - 20.0)	26.0 - 313.0 ppm [182]	5-1, 5-9, 5-16

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Table 5-6. SUMMARY OF EMISSION TEST DATA FOR INCINERATORS BURNING AGRICULTURAL WASTE FROM COTTON GINNING PROCESS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested [no. of tests]	Uncontrolled emissions [mean]	AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]	References
Particulates	1 [9]	4.38 - 9.84 kg/Mg [6.72] (8.78 - 19.73 lb/ton [13.44])	3.5 - 7.5 (7.0 - 15.0)	-	5-12
	1 [4]		3.5 - 7.5 (7.0 - 15.0)	9.25 - 12.7 kg/Mg [11.5] (18.5 - 25.4 lb/ton [23.0])	5-10
NO_x	1 [4]	1243 - 1801 ppm [1615]	1.0 - 1.5 (2.0 - 3.0)	a	5-10
HC	1 [4]	9.7 - 11.7 ppm [10.4]	1.5 - 7.5 (3.0 - 15.0)	a	5-10
CO	1 [4]	0	5.0 - 10.0 (10.0 - 20.0)	a	5-10

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primarily to the scarcity of test data on agricultural waste incinerators. Because the control device was a cyclone, the controlled level would not be expected to be dramatically lower than the uncontrolled level.

Emission rate variations were due primarily to differences in the size and frequency of batches. Emissions were of NO_x, CO, and HC reported in units of flue gas concentration (ppm) and thus cannot be compared to AP-42 emission factors. Furthermore, the NO_x concentration level was surprisingly high. It is not clear whether this level was caused by waste combustion or by the auxiliary fuel used. Both units used natural gas as an auxiliary fuel.

5.1.7 Industrial Incinerators

The bulk of the emission test data on industrial incinerators were on wire and electrical motor incinerators. Other waste categories with relatively large quantities of assembled emission data were chemical liquids and wood. Table 5-7 lists the various wastes and summarizes the emissions test data obtained on each of these categories.

Wire and Electrical Motor Incinerators. Industrial incinerators include incinerators used for reclaiming scrap wire as well as for salvaging electric motors. In each case, insulation is burned away so that the metal can be recovered. For motors the insulation is an enamel or varnish, and for wire it is usually a plastic, generally polyvinyl chloride, but sometimes polyethylene.

Most of the data on wire incinerators were obtained from the Chicago Department of Environmental Control and the Illinois EPA. Table 5-8 summarizes emissions from wire incinerators. Both controlled and uncontrolled emissions data are listed for PM, SO_2, and Cl_2. Emission rates varied with

Table 5-7. COMPILED TEST DATA FROM INDUSTRIAL INCINERATORS

Waste burned	No. of sources	No. of tests	Pollutant sampled	Range in incinerator capacity kg/sec (10^3 lb/hr)	References
Liquid chemical wastes	5	43	particulate, Cl_2 NO_x, HC, CO, SO_2	0.04-0.51 (0.3-4.0)	5-1, 5-8 5-13
Paint racks	1	6	particulate, CO	0.009 (0.070)	5-1
Waste oil	1	28	particulate, CO, HC, NO_x, SO_2, HCl	NA	5-1
Film	2	8	particulate, CO	0.01 (0.07)	5-1, 5-8
Wood waste	3	6	particulate, CO	0.28-0.49 (2.2-3.85)	5-1, 5-12
Wire and electrical motors	14	84	particulate, HCl, Cl_2, NO_x, SO_2, CO, HC	0.02-0.61 (0.12-4.8)	5-1, 5-8, 5-9, 5-11 5-15
Explosive products	1	1	particulate	NA	5-1

Table 5-8. SUMMARY OF EMISSION TEST DATA FROM INCINERATORS BURNING WIRE INSULATION, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]		AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]		References
		kg/Mg (lb/ton) feed	kg/Mg (lb/ton) combustible		kg/Mg (lb/ton) feed	kg/Mg (lb/ton) combustible	
Particulates	11	7.7 - 12.4 [10.5] (15.5 - 24.9 [21.0])	36.1 - 122.5 [58.8] (72.2 - 245.0 [117.6])	3.5 - 7.5 (7.0 - 15.0)	0.63 - 7.45 [3.43] (1.26 - 14.9 [6.86])	12.9 - 28.5 [21.7] (25.8 - 57.1 [43.4])	5-1, 5-8, 5-9, 5-12, 5-15
SO_2	1	-	-	1.25 (2.5)	1.06 - 1.65 [1.39] (2.12 - 3.3 [2.79])	-	5-8
NO_x	2	0.15 - 1.03 [0.67] (0.3 - 2.07 [1.34])	3.22 (6.43)	1.0 - 1.5 (2.0 - 3.0)	-	-	5-8
HC	1	0.15 - 1.75 [1.2] (0.3 - 3.5 [2.4])	1.85 - 15.5 [5.4] (3.7 - 31.0 [10.8])	1.5 - 7.5 (3.0 - 15.0)	-	-	5-8
Cl_2	2	20.2 - 39.1 [28.8] (40.3 - 78.2 [57.7])	104.7 - 121.0 [113.0] (209.4 - 242.1 [226.1])	NA	5.85 - 13.3 [9.5] (11.7 - 26.5)	32.3 - 40.0 [37.1] (64.6 - 80.0 [74.2])	5-8
CO	5	-	-	5.0 - 10.0 (10.0 - 20.0)	74 - 3100 ppm[a] [1020]	-	5-1, 5-8

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[a] At 50% excess air.

batch size, frequency of charging, rate of auxiliary fuel use (usually natural gas), and the type of insulation burned (PVC, neoprene, rubber, cloth). Emission factors listed in Table 5-8 are given on a total weight feed basis as well as on a combustible feed basis. Typically, 25 to 30 percent of the weight charged to the wire incinerators was combustible. The average uncontrolled particulate emission factor of 58.8 g/kg (117.6 lb/ton) of combustible feed was calculated from test information on five incinerators. One source in particular, a combination aluminum sweat furnace and wire incinerator, emitted particulates as high as 122.5 g/kg (245.0 lb/ton) of combustible feed. The data compiled indicate that uncontrolled particulate emissions from wire incinerators are significantly higher than the AP-42 emission factors of 3.5 to 7.5 g/kg (7 to 15 lb/ton) for general industrial incinerators.

Afterburners and wet scrubbers, sometimes using caustic water, serve as control equipment. The particulate emissions from wire incinerators that used a scrubber for emission control ranged from 0.03 to 7.45 g/kg (1.26 to 14.91 lb/ton). The particulate emissions from units having only afterburner controls ranged from 2.33 to 4.15 g/kg (4.67 to 8.30 lb/ton). Therefore, of the two control technologies, scrubbers produced both the highest and the lowest emission control levels. This inconsistency can be rationalized by several hypothetical scenarios such as different scrubber designs or different wastes; however, no information that could resolve the question was given in the test report.

Because polyvinyl chloride is often used in insulation, chlorine emissions, along with PM, SO_2, NO_x, and NMHC emissions, were measured. Uncontrolled Cl_2 emissions averaged 28.8 g/kg (57.7 lb/ton) of total feed; controlled emissions averaged 33 percent of the uncontrolled rate.

Most of the test data on electric motor incinerators were obtained from the Air Protection Branch of the Georgia Environmental Protection Division. Emissions from these incinerators are summarized in Table 5-9. None of the tests measured controlled emissions. The nature of the waste feed and the different types of insulation used on motor windings cause combustibles to average 2 percent by weight of the total incinerator feed. Particulate matter emissions ranged from about 1.5 to 5 g/kg (3 to 10 lb/ton) of combustible feed. Average emisson rates for PM, SO_2, HC, and CO are all lower than the emission factor ranges reported in AP-42. The NO_x emissions are higher by a factor of 4 than those reported in AP-42.

Liquid Waste Incinerators. Liquid waste incinerators dispose of a variety of liquid wastes, primarily polychlorinated waste, waste oil, and various other hydrocarbon liquids. Table 5-10 presents data on five liquid waste incinerators. Most of the emission data gathered in this category were obtained from the Illinois and Georgia State agencies and from published test reports. Uncontrolled particulate emissions fell within the range of AP-42 emission factors for single- and multi-chamber industrial incinerators. These emissions were controlled with a variety of equipment, including venturi scrubbers, cyclones, quench towers, and packed ring towers. Average controlled PM emissions were 50 percent of the uncontrolled emissions.

Test data were lacking or inconclusive for the other pollutants. For example, controlled HCl emissions averaged higher than uncontrolled emissions, primarily because two of the three sources tested were in either the uncontrolled or controlled mode of operation, but not in both. Therefore, the effectiveness of a control device cannot be identified without additional data. Additional test data have been identified by the EPA Region V Office.

Table 5-9. SUMMARY OF UNCONTROLLED EMISSION TEST DATA FROM ELECTRIC MOTOR INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Emissions[a] kg/Mg (lb/ton) [mean]	AP-42 emission factor kg/Mg (lb/ton)	References
Particulates	11	1.5 - 5.22 [2.62] (3.0 - 10.44 [5.24])	3.5 - 7.5 (7.0 - 15.0)	5-8
SO_2[b]	10	0.95 - 0.22 [0.185] (0.19 - 0.44 [0.27])	1.25 (2.5)	5-8
NO_x[c]	9	2.23 - 4.68 [3.18] (4.46 - 9.36 [6.36])	1.0 - 1.5 (2.0 - 3.0)	5-8
HC	8	0.385 - 0.53 [0.54] (0.77 - 1.06 [1.08])	1.5 - 7.5 (3.0 - 15.0)	5-8
CO	8	1.08 - 2.38 [2.5] (2.17 - 4.67 [5.00])	5.0 - 10.0 (10.0 - 20.0)	5-8

T-0075

[a] Based on combustible feed.

[b] Additional test data show emissions of 2.14-30.0 ppm SO_2.

[c] Additional test data show emissions of 38.7-48.4 ppm NO_x.

Table 5-10. SUMMARY OF EMISSION TEST DATA FROM LIQUID WASTE INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	No. of sources tested	Uncontrolled emissions [mean]	AP-42 emission factor kg/Mg (lb/ton)	Controlled emissions [mean]	References
Particulates	5	4.15 - 7.63 kg/Mg [5.8] (8.3 - 15.26 lb/ton [11.6])	3.5 - 7.5 (7.0 - 15.0)	0.09 - 9.72 kg/Mg [2.91] (0.18 - 19.44 lb/ton [5.81])	5-1, 5-8, 5-13, 5-14
SO_2	1	-	1.75 (2.50)	1.07 - 3.06 kg/Mg [1.92] (2.14 - 6.51 lb/ton [3.85])	5-13
NO_x	2	180.0 - 933.0 ng/J [417.0] (0.42 - 2.17 lb/10^6 Btu [0.27])	1.0 - 1.5 (2.0 - 3.0)		5-1, 5-13
HC	2	-	1.5 - 7.5	0.35 - 3.2 kg/Mg [1.26] (0.71 - 6.45 lb/ton [2.53])	5-1, 5-8
HCl	3	0.36 - 0.81 kg/Mg [0.59] (0.72 - 1.61 lb/ton [1.191])	-	0.65 - 3.46 kg/Mg [1.68] (1.31 - 6.92 lb/ton [3.36])	5-1, 5-8, 5-13
CO	1	-	5.0 - 10.0 (10.0 - 20.0)	13 - 20 ppm @ 50% excess air	5-1

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However, these data were not received in time to be incorporated into this report.

Paint Racks, Wood, and Film Incinerators. Data were obtained on additional incinerators burning wastes such as paint racks, waste filters, waste wood, and paper. Table 5-11 summarizes emissions from these sources. Sources of data included the state agencies of Georgia and Illinois. Uncontrolled PM emissions comprise most of the data; carbon monoxide was the only other pollutant tested. Grain loading was the most common method of reporting emissions from these sources.

Summary of Particulate Data. The particulate emission data have been summarized in Table 5-12. All emission measurements not previously converted to g/kg (lb/ton) were converted for this table based on the conversion factors in Table 3-3.

5.2 SUMMARY OF EMISSION COLLECTION AND ANALYSIS PROCEDURES

Several test methods were used to measure emissions from incinerators. All these methods for measurements of criteria and noncriteria pollutants were separated into the following five categories:

- Tests approved by the EPA
- Modified EPA-approved tests
- Tests using continuous monitoring instrumentation
- Not EPA-approved tests
- Not specified tests

Table 5-13 lists the number of tests gathered in this program for each of the five categories.

The "EPA-approved" category includes those tests which were performed using EPA-approved sampling, measurement, and analysis methods. For example,

Table 5-11. SUMMARY OF EMISSION TEST DATA FROM OTHER INDUSTRIAL INCINERATORS, SI UNITS (ENGLISH UNITS)

Pollutant	Waste	No. of sources tested	AP-42 emission factor kg/Mg (lb/ton)	Mean uncontrolled emissions	Mean controlled emissions	References
Particulates	paint racks	1	3.5 - 7.5 (7.0 - 15.0)	0.10 g/m^3 (0.044 gr/scf)	-	5-1
	film	1	3.5 - 7.5 (7.0 - 15.0)	3.1 kg/Mg (6.2 lb/ton)	-	5-8
	wood scrap	2	3.5 - 7.5 (7.0 - 15.0)	0.06 g/m^3 (0.027 gr/scf)		5-1
		1	(7.0 - 15.0)		0.07 g/m^3[a] (0.031 gr/scf[a])	
	paper drums[b]	1	3.5 - 7.5 (7.0 - 15.0)	0.41 g/m^3 (0.18 gr/scf)	-	5-1
CO	paint racks	1	5.0 - 10.0 (10.0 - 20.0)	556 ppm	-	5-1
	wood scrap	3	5.0 - 10.0 (10.0 - 20.0)	556 ppm	310 ppm	5-1

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[a] Wet spray collector, a low efficiency collection device.

[b] Paper drums burned with smokeless powder and activated charcoal.

Table 5-12. SUMMARY OF PARTICULATE EMISSION DATA COLLECTED

Incinerator use	Uncontrolled kg/Mg (lb/ton)	Controlled kg/Mg (lb/ton)	AP-42 kg/Mg (lb/ton)
Municipal	0.15-19.0 (0.3-38.1)	0.37-0.91 (0.73-1.82)	7.5-15 (15-30)
Pathological	0.52-16.3 (1.04-32.61)	0.05-17.1 (0.10-34.2)	4 8
Sludge	1.3-7.3 (2.6-14.6)	0.09-3.3 (0.18-6.6)	50 100
Trash	0.06-4.05 (0.13-8.11)	0.35-1.0 (0.70-2.0)	3.5-7.5 7-15
Gin waste	4.38-9.84 (8.78-19.73)	13.23-18.3 (26.27-37.57)	3.5-7.5 7-15
Wire[a]	7.7-12.4 (15.5-24.9)	0.63-7.45 (1.26-14.91)	3.5-7.5 7-15
Wire[b]	36.1-122.5 (72.2-245)	12.9-28.5 (25.8-57.11)	3.5-7.5 7-15
Motors	1.5-5.22 (3.0-10.44)	-	3.5-7.5 7-15
Liquid waste	4.1-7.63 (8.3-15.26)	0.09-9.72 (0.18-19.44)	3.5-7.5 7-15
Paint rack	0.36 (0.73)	-	3.5-7.5 7-15
Film	3.1 (6.2)	-	3.5-7.5 7-15
Wood	0.22 (0.45)	0.26 (0.52)	3.5-7.5 7-15

[a] per Mg(ton) feed

[b] per Mg(ton) combustible

Table 5-13. SUMMARY OF TEST METHODS - INCINERATORS

	Number of tests				
Source type	EPA-approved	Modified EPA-approved	Continuous monitoring	Not EPA approved	Not specified
Municipal refuse incinerators	37	2	0	3	0
Pathological incinerators	47	7	0	8	75
Sewage and ind. sludge incinerators	20	0	1	8	42
Agricultural refuse incinerators	10	0	0	0	0
Trash and rubbish incinerators	107	4	0	26	34
General ind. refuse incinerators	55	2	1	7	17
TOTAL	276	15	2	52	168
PERCENT OF TOTAL	54	2	1	10	33

particulate emissions were measured using Test Methods 1 through 5 published by EPA in the Code of Federal Regulations (CFR). Similarly, SO_2 and NO_x emissions were tested using EPA-approved Methods 6 and 7, also published in 40 CFR 60 App. A.

The large majority of incinerators burning municipal waste, agricultural refuse, trash and rubbish, and general industrial refuse were tested with EPA reference methods. Overall, 54 percent of the incinerators were reported to have been specifically tested with EPA reference methods.

Modified EPA-approved tests included those tests that specifically reported using equipment and/or procedures similar to but not exactly the same as those approved by the EPA. The deviations were often suggested by the State air pollution agencies responsible for the tests. For example, in a few instances, the impinger section of the equipment assembly for particulate emission testing was modified to allow for combined sampling of PM and SO_2 and noncriteria pollutants such as Hg or Cl_2. The combined pollutant sampling procedures, however, represent approved deviations from the specified EPA Test Method 5. Particulate emission sampling using modified EPA equipment and procedures comprised only 2 percent of the total. Often, detailed information on field test procedures and equipment was not available. Only those tests which specifically reported some deviation from EPA methodology were counted as something other than EPA-approved.

Continuous monitoring instrumentation is often used to measure gaseous emissions of pollutants such as NO_x, CO, and, at times, SO_2. Even though the FEDERAL REGISTER requires wet chemical analysis for most of these pollutants, continuous monitoring with electronic instrumentation is also approved as a reliable measurement technique. For incinerator emission data summarized in this report, continuous monitoring was used primarily to measure emissions from sludge and industrial refuse incinerators. Only 2 percent of the tests specifically reported using continuous monitoring. This low percentage reflects the small number of tests performed to measure emissions of pollutants other than particulates.

The non-EPA approved category primarily included all particulate tests using the ASME Method. Before 1971, the ASME method of PM measurement was generally used because the EPA had not yet standardized its procedure. The ASME Method measured in-stack PM at the actual stack temperature. However, EPA Test Method 5 measures PM at a constant 121°C (250°F) regardless of actual stack temperature. In addition, Test Method 5 includes filter specifications which are considerably more stringent than ASME filter specifications. The implications are that although the two methods may give nearly identical measurements of uncontrolled emissions, their measurements of controlled emissions may differ significantly, especially if the stack temperature is relatively low.

Approximately 35 percent of all field test data did not specify either the equipment or the procedure used. However, it can be assumed that, in most cases, EPA-approved or modified-approved test methods were probably used because much of the data were obtained by State and local air pollution control agencies, which generally follow accepted test procedures in determining regulatory compliance of a source. Thus, the methods used in most tests with unspecified equipment or procedures were acceptable to the State agency and probably to the EPA.

The EPA test methods, as published in the FEDERAL REGISTER, are generally applicable to the measurement of air pollutants from incinerators. Municipal incinerators are similar in size and operation to stoker-fed industrial-sized boilers burning coal.

EPA sampling procedures have been used successfully to report representative emissions from those sources. However, the applicability of EPA Method 5 (PM measurement) to the accurate measurement of emissions from much smaller industrial and commercial incinerators, such as those burning trash and general refuse, may be in question for two reasons. First, the stacks from small incinerators may not be long enough to permit sampling at the necessary distance (either upstream or downstream) from a disturbance in stack gas flow. Second, the inner diameter of many stacks may be so small that wall effects (on gas flow) can be significant, thus invalidating the test procedure. However, these comments are only speculative because the time constraints of this program did not allow an in-depth analysis of field test procedures; therefore, potential sources of error that might invalidate the data could not be identified.

5.3 LOCAL AMBIENT IMPACT

One criterion for determining priorities in establishing an NSPS is the extent to which the pollutants from the source category may reasonably be anticipated to endanger public health. This criterion has been evaluated by estimating the local impact for a typical new industrial incinerator. Results are presented here only for motor and small capacity wire incinerators because they are the only ones that will be manufactured in any noticeable quantities in the future. Table 5-14 summarizes the maximum 24-hour average ground level concentrations.

Table 5-14. MAXIMUM 24-HOUR AVERAGE GROUND LEVEL CONCENTRATIONS OF PARTICULATE MATTER
(Subcategories with New Installation Activity)

Population segment	Classification	Capacity (lb/hr)	Estimated ground level concentration ($\mu g/m^3$)
Electric motor	Typical	500	16
Copper wire	Typical	1000	26

The local impact of an incinerator was evaluated by calculating ground level concentrations by the procedures in Turner's Workbook of Atmospheric Dispersion Estimates. The methodology in the workbook is most applicable to gaseous pollutants. However, the particulate emissions are assumed to be light enough to behave similarly to a gas. In actuality, the heavier particulates will fall out of the plume. So this approach will tend to overestimate concentrations.

To estimate the maximum probable impact, some worst case assumptions have been made. It is assumed that the units will operate at full capacity and that they run continuously for 8 hours. Generally none of these units runs at the maximum capacity. Motor incinerators typically only run at 20 percent of their capacity. An emission level of 0.2 grains/dscf was used for all the units that were modeled. This emission level was selected because 62 percent of all States and an even higher percentage of heavily industrialized States have an emission limitation equal to or less than 0.2 gr/dscf. Most resource recovery incinerators are subject to a 0.1 gr/dscf emission standard. Very low vertical mixing was assumed and class F stability was selected. These conditions occur only with high cloud cover and 2-3 mile per hour winds. All these assumptions should provide an overestimate of the maximum ground level concentrations.

The stack parameters which are summarized in Table 5-15 chosen for each of the incinerators were values that were given for actual units in test reports, permit applications, and manufacturers' literature. The maximum value of 26 micrograms per cubic meter is 10 percent of the 24-hour national primary ambient air quality standard for particulate matter. In light of all the worst case assumptions made in deriving the concentration, the local impacts of these units do not provide a strong reason to develop a standard.

Table 5-15. STACK PARAMETERS

Stack parameters	Copper wire incinerator	Electric motor incinerator
Height (m)	7.62	4.57
Diameter (m)	0.61	0.26
Temperature (°K)	422.0	449.0
Velocity (m/s)	2.43	4.57
Volumetric flow (m^3/s)	0.708	0.233
PM emissions (g/s)	0.324	0.107

5.4 NATIONWIDE EMISSIONS AND POTENTIAL BENEFIT

To assess the relative importance of present development of an NSPS for this source category, total nationwide emission rates were estimated for the entire population of industrial incinerators. The potential benefit from an NSPS has also been estimated as the total tons of particulate matter a standard would have the potential to prevent from entering the atmosphere each year.

For 1978 and 1983, the SIP estimates were based on the typical SIP level of 0.2 grains per dry standard cubic foot (gr/dscf) for all incinerators except conical units. The conical national emissions estimate was obtained directly from available literature. The typical SIP emission level based on conversion factors given in Chapter 3 is equivalent to 1.67 kg of particulate matter per megagram (Mg) of waste (3.33 lb/ton). The 1978 and 1983 SIP emission levels for the volume reduction, toxicity reduction, and off-site segments were calculated as the product of the total waste processed and the 1.67 kg/Mg emission factor. The total waste processed by the volume reduction and toxicity reduction population segments was calculated as the product of the number of units in Table 4-14, the mean capacities in Table 4-7, and the mean annual hours of operation in Table 4-9. The results are presented in Table 5-16.

Table 5-16. PROJECTED WASTE PROCESSED ANNUALLY IN INDUSTRIAL INCINERATORS

Population segment	Waste processed annually in thousands of megagrams (thousand tons)	
	1980	1985
Volume reduction	760 (840)	550 (610)
Toxicity reduction	1800 (2000)	1200 (1300)

The annual amount of waste processed at a typical off-site incinerator was estimated from available literature at 23,420 Mg (26,762 tons) per year.[19] The number of units has been estimated at 10 for both 1980 and 1985, giving a total annual amount of waste processed of 234,000 Mg (267,000 tons).

The national emissions from the resource recovery segment of the population were estimated by disaggregating the group into its six major subcategories--copper wire, electric motor, x-ray film, steel drum, brake shoes, and other. The SIP level emissions for typical copper wire and electric motor units are 3.3 and 0.23 Mg (3.6 and 0.2 tons) per year, respectively. This assumes typical capacities of 230 kg/hr (500lb/hr) for electric motor units and 450 kg/hr (1,000 lb/hr) for copper wire units. The nationwide emissions for these two subcategories were estimated as the product of the annual SIP level emission factor for a typical unit and the population estimates from Chapter 4. The nationwide emissions of the remaining subcategories of resource recovery units were estimated as the product of the 1.67 kg/Mg (3.33 lb/ton) emission factor, the average capacity, the annual hours of operation for the resource recovery segment as shown in Tables 4-7 and 4-9, and the population estimates for each subcategory discussed in Chapter 4.

The projected 1980 and 1985 nationwide particulate emissions for the industrial incinerator population are summarized in Table 5-17. A 60 percent drop in total particulate emissions is projected over the next 5 years, due almost entirely to the shrinking population size, because of minimal new installations and rapid obsolescence of existing units. The only population segment for which an increase in nationwide emissions is projected is the resource recovery unit population. This segment will experience a 30 percent increase in population size and only a 5 percent increase in total emissions. This disproportionate change in emissions is a result of expansion in the population of resource recovery units attributable almost entirely to electric motor incinerators. These units typically emit 0.23 Mg (0.25 tons) of particulate matter per year, a relatively small amount compared to the 1978 average emissions for all resource recovery units of 1.2 Mg (1.3 tons).

Table 5-17. PROJECTED NATIONWIDE PARTICULATE EMISSIONS, MEGAGRAMS/YEAR (TONS/YEAR)

Population segment	Emission level 1980 SIP	 1985 SIP
Volume reduction	1300 (1400)	920 (1000)
Toxicity reduction	3000 (3300)	2000 (2200)
Resource recovery	2100 (2300)	2200 (2400)
Off-site	390 (430)	390 (430)
Conical	9100 (10000)	820 (900)
TOTAL	16000 (18000)	6300 (6900)

The potential benefit from an NSPS has been measured in terms of the amount of particulate matter a standard would have the potential to prevent from entering the atmosphere each year. The uncontrolled, SIP, and potential NSPS emissions are summarized in Table 5-18 for the total new installation population and typical individual units. The segments for which new installations are expected are the volume reduction, toxicity reduction, electric motor, copper wire, and other subcategories of the resource recovery segment. The maximum benefit from an NSPS is the pollutant reduction that can be obtained in addition to what the SIPs already require. The expected reduction for typical units is 0.42 Mg (0.46 ton) for volume reduction and 1.7 Mg (1.8 tons) for toxicity reduction. This reduction is estimated at 0.23 and 3.3 Mg (0.25 and 3.6 tons) of particulates per year for electric motor and copper wire incinerators, respectively. This would result in a maximum nationwide particulate matter benefit for the entire new installation population of only 250 Mg/yr (280 tons/yr).

Regulations for the operation of hazardous waste incinerators that were proposed December 18, 1978, under the Resource Conservation and Recovery Act (RCRA) limit the emissions from affected incinerators to 0.08 gr/dscf. If these regulations are promulgated, they would reduce the benefit to be derived from an NSPS. If RCRA were to be applicable only to the off-side and toxicity segments, the benefit of an NSPS would be reduced to 200 Mg (220 tons) of particulate matter to be prevented from entering the atmosphere each year by 1985. However, the hazardous

Table 5-18. NATIONWIDE EMISSIONS FROM NEW INDUSTRIAL INCINERATORS

Population segment	Subcategory	Typical capacity kg/hr (lb/hr)	No. of new installations (1978-1983)	Particulate matter emissions, megagrams/year (tons/yr)[a]							
				Typical unit				Total population			
				Uncontrolled	SIP[b]	NSPS[c]	Maximum (Ts - Tn)	Uncontrolled	SIP[b] (Ts)	NSPS[c] (Tn)	Maximum (Ts - Tn)
Volume reduction	All	202 (445)	63	3.2 (3.5)	0.70 (0.77)	0.28 (0.31)	0.42 (0.46)	200 (220)	44 (49)	18 (20)	26 (29)
Toxicity reduction	All	368 (310)	32	21 (23)	2.8 (3.0)	1.1 (1.2)	1.7 (1.8)	670 (700)	90 (96)	35 (38)	54 (58)
Resource recovery	Electric motor	230 (500)	500	3.3 (3.6)	0.23 (0.25)	0.018 (0.020)	0.21 (0.23)	1700 (1900)	110 (120)	9 (10)	100 (110)
	Copper wire[d]	450 (1000)	25	41 (45)	3.3 (3.6)	0.36 (0.40)	2.9 (3.2)	1100 (1200)	82 (90)	9 (10)	73 (80)
							TOTAL	3700 (4000)	330 (360)	71 (78)	250 (280)

Note: The values in this table do not sum exactly because of unit conversions, rounding, and the maintenance of two significant figures.

[a] Assumes 7480 hours of operation annually at full capacity for toxicity reduction units and 2080 hours of operation annually at full capacity for all other units.

[b] Typical SIP level of 0.2 gr/dscf.

[c] Based on hypothetical NSPS of 0.08 gr/dscf for volume and toxicity reduction units and the lowest emission rate per weight of feed found in available test data for resource recovery units.

[d] The values are for small capacity units; no new installations of large units are expected.

waste incinerator regulations may apply to a cross-section of the industrial incinerator population. If so, the benefit to be derived from an NSPS would be reduced even further.

Some of the same factors that are reducing the potential benefit that can be expected from an industrial incinerator NSPS are increasing the potential benefit from a nonfossil-fueled boiler (NFFB) NSPS. Nonfossil-fueled boilers and land disposal techniques are, in some cases, economically attractive alternatives to incineration. As RCRA requirements and decreasing land availability attach additional economic burdens to land disposal, and as increased fossil fuel costs improve the economics of nonfossil fuels as an energy source, there will be additional incentive for nonfossil-fueled boiler new installation activity. The greater this new installation activity, the greater will be the potential benefit of an NSPS for NFFBs.

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6. CONTROL TECHNOLOGIES

Particulate matter is the only air pollutant emitted from incinerators for which control devices are generally applied. The other air pollutants normally associated with incinerators--visible emissions and odor--are controlled by proper operation of the incinerator. Gaseous air pollutants, such as NO_x and SO_2, are generally not emitted from incinerators in sufficient quantity to have warranted control to date. The sulfur content of the material generally being incinerated is usually low, and the combustion temperature is usually too low to create large amounts of NO_x. Exceptions are incinerators that burn materials high in sulfur or nitrogen content and slagging incinerators that reach combustion temperatures above 3000°F, at which substantial amounts of NO_x are formed.

6.1 CURRENT CONTROL TECHNOLOGY

Current particulate control technologies for industrial incinerators include afterburners, scrubbers, and baghouses. Afterburners are used on all the units for which the controls are known and were located during this study. No uncontrolled units were located; apparently, existing regulations have been effective in implementing minimum controls at least on units included in the State records. The supplemental data collected on resource recovery units revealed some operating incinerators equipped with air pollution controls in addition to afterburners. Sources of the supplemental data on resource recovery incinerators included numerous manufacturers and owners, 22 State air pollution agencies, and 16 local agencies. The operating control technologies are summarized in Table 6-1.

Table 6-1. DEMONSTRATED CONTROL TECHNOLOGIES

Population segment	Control technology Afterburner	Wet scrubber	Fabric filter
Copper wire	X	X	
Electric motor	X		
X-ray film	X	X	X
Steel drum	X		
Brake shoes	X		

Afterburners are used to control particulates on all resource recovery units located during this study. Tests using afterburners have shown particulate emission reductions in excess of 90 percent on wire, brake, and motor incinerators.[1] This control device is usually sufficient to meet SIP emission limitations, and, since afterburners have historically been the least expensive control method, they have been universally applied for regulatory compliance.

From an existing population of over 1,000 units, 12 operating units were located with additional controls downstream from the afterburner. No brake, motor, or drum units equipped with additional controls were located. One owner of a drum incinerator tried to control emissions with a scrubber, but the system failed because of poor design and is no longer in use.[2]

Scrubbers have been demonstrated on both wire and x-ray incinerators. They are used in conjunction with, rather than in place of, the afterburner. Both wire and x-ray incineration can result in some emissions of acid gases and chlorine. The scrubbers are installed primarily to control those pollutants rather than the particulate matter.

Six units with scrubbers were located with the help of State agencies. The State records did not contain any design data. The contacts at two sites refused to submit any information over the telephone. Three other sites were visited. All three scrubbers were low efficiency systems, bubblers and spray chambers, with pressure drops of less than 10 inches of water. No test data were obtained for any of the scrubbers.[3]

The high price of auxiliary fuel motivated one owner of a wire incinerator to try to replace an afterburner with a scrubber to control particulates. The unit controlled by the scrubber alone was unable to meet the State visible emissions regulation and had to be shut down. The failure was attributed by the operator of the facility to a poorly designed scrubber rather than to the inability of the technology to attain compliance.[4]

On the incinerators surveyed, baghouses are in use only on x-ray units and have been installed only in conjunction with an afterburner, a waste heat boiler, and a scrubber. A package system including all the controls is now being sold by one supplier. The location of one unit is known, and six other undisclosed installations exist.[5] One scrap yard tried to use a baghouse to control the emissions from a wire incinerator, but because of problems with visible emissions, the incinerator is no longer in use.[6]

6.2 TECHNOLOGY TRANSFER AND EMERGING TECHNOLOGY

Most of the established control technologies for fossil-fueled combustors, such as ESPs and baghouses, have already been applied to municipal incinerators. Most are likely to be applicable to the industrial incinerator category as well because of waste and equipment similarities. Also, research is being conducted on fabric filter design in an effort to produce a fabric filter that can withstand the temperature excursions encountered in incinerator applications. Emerging technologies for fossil-fueled combustors are candidates for additional technology transfer. For instance, fluidized bed combustion is currently an emerging technology for fossil-fueled combustors and is at least a proven technology for certain types of waste for incinerators. Phenol and methyl methacrylate wastes have been destroyed in an FBC incinerator.[7]

Some new control techniques being used in limited applications with waste-fired combustors could also be used on incinerators. Dry scrubbers or gravel-bed filters are being used on some wood waste-fired boilers with varying degrees of success.[8]

6.4 REFERENCES

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7. RECOMMENDATIONS

Based on the results of this study, the following recommendations are made:

1. EPA should not move toward promulgating a new source performance standard for industrial incinerators based on data collected at the time of this study. This recommendation is based on the conclusion that an NSPS would not have a substantial impact on future emissions from this source category because:
   a. New installation activity is very limited except for very small capacity units which have relatively insignificant emissions.
   b. Existing SIPs effectively limit particulate emissions to 90 percent of the uncontrolled level. Containing the remaining 10 percent (theoretical limit) of particulate emissions from the new installations that are projected over the next 5 years is a small maximum benefit when compared to the potential benefit from developing NSPS for other categories.
   c. Incinerators are being phased out in favor of landfills and nonfossil fuel-fired boilers.
2. In the event background data are collected for a standard, the industrial incinerator source category should be further classified into subcategories based on incinerator use because the economic, energy, and environmental factors that will influence the respective impact analyses will be highly dependent upon the unit's use. Different emission limits should be considered for each subcategory. The proposed classifications are: